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Sheep Reproduction RD&E Impact Assessment

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Executive Summary

Improving lamb survivability on-farm is a key priority for Australian sheep and wool producers. The peak industry councils, WoolProducers Australia (WPA) and Sheep Producers Australia (SPA), Animal Health Australia (AHA) and the industry research and development corporations (RDCs), Meat and Livestock Australia (MLA) and Australian Wool Innovation (AWI), share a commitment to increasing lamb survivability through industry research, development, extension (RD&E) and adoption of relevant on-farm management practices. Following completion of the Sheep Reproduction RD&E Investment Plan 2012-2017 (SRRIP) and a recent stock-take of ongoing RD&E projects, the industry is now seeking to develop new strategies and initiatives to further improve lamb survivability outcomes.

Beattie Consulting Services and Inspiring Excellence were engaged by MLA on behalf of the project partners to conduct an independent impact assessment of sheep reproduction RD&E since inception of the SRRIP. The evaluation was undertaken to review and assess the benefits, costs and impacts of current and recently completed RD&E activities against key industry performance targets, to review industry collaboration on sheep reproduction, and to identify any remaining gaps in sheep reproduction RD&E. The evaluation process included the review and assessment of 120 project investments, and an extensive stakeholder engagement process involving one-hundred stakeholders engaged via phone interviews and an online survey.

Key Findings

The following key findings were identified during the review process. All findings are provided in Appendix A.

Value Proposition for Increasing Sheep Reproduction Efficiency

- During the review process, stakeholders identified the key industry benefits from increasing ewe reproduction rate as increasing the size of the national flock, increasing sustainability of the supply chain, increasing animal welfare and environmental outcomes, and increasing farm profitability.
- While increasing the size of the national sheep flock is a priority at a national level, it is not necessarily a priority for individual producers. At the farm level, increasing the size of the national flock is not an objective that influences decision making, and increasing reproductive rate will not necessarily lead to increases in the size of the national flock.
- Increasing animal welfare by increasing lamb survival is a high priority for the industry, however there is a conflict between increasing ewe fertility as a priority and the lower lamb survival of twin and triplet lambs in the extensive conditions on Australian farms.
- Increasing community calls for reducing red meat consumption amidst concerns around greenhouse gas emissions has prompted the red meat industry to set a target of carbon neutral red meat production by 2030. Greater investment in increasing lamb survival and reproductive rate of ewe lambs are key opportunities to assist industry in meeting this target.
- Some of the extension messages provided to producers, particularly wool producers running self-replacing Merino flocks, are potentially counterproductive to the industry objective of increasing lamb survival.

- The level of lamb survival considered to be acceptable by society and consumers is likely to be higher than the collective level of lamb survival achieved on individual farms aiming to maximise farm profit within limited resource boundaries, thus representing a potential market failure which may require additional government and industry funding to address.

Industry Investment in Sheep Reproduction

- Total investment in sheep reproduction RD&E for projects contracted during the SRRIP investment period (2012/13 to 2016/17) was $20.71 million, which is 16% less than the $24.70 million recommended in the SRRIP. Expenditure only includes investment in projects where MLA and/or AWI provided funding (investment data where RDCs were not involved was unavailable for this review), either in part or wholly, and includes cash and in-kind co-investment from delivery partners.
- The value of total industry investment in development and extension activities between 2012/13 and 2016/17 has been around two-thirds of that recommended in the SRRIP (2012-2017).
- Relative to what was recommended in the SRRIP, the proportion of total expenditure on sheep reproduction has been 83% higher on applied research, 40% lower on development and extension, and 55% lower on strategic research.
- Over the SRRIP delivery period, proportional investment in the 'Conception and early embryo mortality' and 'Genetics and biological mechanisms' pillars was higher than that recommended in the SRRIP, while relative investment in the 'Ewe and lamb survival' and 'Early reproductive success and weaner performance' pillars was lower than that recommended.
- Based on an estimate of the split of costs and benefits between investment pillars for projects included in the impact assessment for this review, had investment been apportioned between pillars according to the recommendations in the SRRIP, rather than what actually occurred, it is estimated that an additional $6.62 million in net present value terms would have been generated from that investment.
- To provide a more representative estimate of the benefits foregone by not following the recommended proportional investment by pillar in the SRRIP, one outlier project which skewed the B:C ratio considerably for the 'Conception and early embryo mortality pillar' was removed from the analysis as a comparison. This project represented a very small proportion of total investment in the pillar (4%) for the projects assessed, but accounted for the majority of benefits (75%). Removing the project from the analysis reduced the B:C ratio for the 'Conception and early embryo mortality' investment pillar by 75%. With removal of the outlier project, the estimated additional net present value which could have been generated by following the proportional investment by pillar recommended in the SRRIP was $12.68 million.

Utilisation of the SRRIP in Guiding Sheep Reproduction Investment

- The stakeholder engagement process indicates broad industry support for a National Sheep Reproduction RD&E Investment Plan, however it was found during the review that the SRRIP has not been effectively utilised over the term of its life to guide project investment decisions for sheep reproduction RD&E.
- Overall, there was a lack of resourcing to support ongoing governance planning and accountability to ensure that the SRRIP was effectively implemented and monitored to achieve its objectives.

- For a new SRRIP to be successfully implemented it would require formal commitment from all industry partners, including RDCs, producer organisations, researchers, and public and private extension providers and advisors, for the duration of the planning period.
- According to stakeholder feedback, relative to the perceived importance of the issue of lamb survival to the sheep industry, the level of funding allocated by the RDCs to sheep reproduction RD&E, particularly to development and extension activities, is considered to be inadequate to achieve the desired industry outcomes for lamb survival.

Sheep Reproduction RD&E Achievements

- Since inception of the SRRIP, there has been a considerable amount of sheep reproduction R&D which has generated new knowledge to address information gaps, but much of which has not translated to adoptable products to increase reproduction efficiency on farms.
- Of all of the extension products delivered during the review period, the Lifetime Ewe Management program has had the most influence on sheep reproduction efficiency, impacting the management of around 6 million ewes in the past 6 years. However, over recent years the impact of the program on delivering producer gains in reproduction and ewe mortality has declined, largely due to an increase in the level of best management practices already being undertaken by producers before they engage in the LTEM program.
- The overall objective of the SRRIP was for a 10% increase in sheep reproduction rate over the 5-year planning period (average annual gain of 2%). This objective was not achieved, with the average annual rate of gain being between 0.6% and 1.5% (adjusted for changes in the proportion of Merino versus other ewe breeds over time), depending on the source of data utilised. This rate of gain was highly likely to have been negatively influenced by below average seasonal conditions during the SRRIP delivery period.
- The average annual rate of gain in marking rates during the SRRIP delivery period was between 1.0% and 1.4% for Merino lambs and between 0.6% and 1.7% for all other lambs, again depending on the data source.
- As a single indicator for measuring change in sheep reproduction efficiency over time, lamb marking rate has several key limitations, however there is no national time series data available to measure success against any other numerical key performance indicators for sheep reproduction identified in industry strategic plans.
- Seasonal variation has a considerable impact on ewe reproduction rate, which makes it difficult to accurately assess the impact of investment in RD&E on national sheep reproduction outcomes.
- The impact of project investments where an adoption output and an adoption pathway were evident ranged between zero and $3.91 per ewe. Utilising a 5% discount rate over a 25-year time period, the overall economic assessment of all projects where an adoption output and an adoption pathway were evident returned a net present value (NPV) to industry of $93.40 million, with a benefit cost ratio (B:C ratio) of 5.2 and an internal rate of return of 39%.
- A sensitivity analysis of the impact assessment found that with a 20% higher rate of productivity gain and a 20% higher value of additional lambs weaned, RD&E investment returned a NPV of $197.84 million with a B:C ratio of 9.9, and with a 20% lower rate of productivity gain and a 20% lower value of additional lambs weaned, the NPV was $19.21 million with a B:C ratio of 1.9.

Key Gaps in Sheep Reproduction RD&E

- It was the general view of stakeholders that research to date has provided answers to a large number of sheep reproduction issues, however that knowledge has not been well applied and adapted to different systems and zones to facilitate broad industry adoption.
- Feedback from some stakeholders suggested that the project funding model is overly reliant on priorities identified by SALRC/WALRC, without sufficient consideration for 'what they don't know'. It was also considered by many that investment priorities change too quickly, and that a longer-term approach to sheep reproduction R&D is required.
- Stakeholder feedback suggests that consultants who work directly with producer clients are an underutilised resource in the R&D process, and that there is an opportunity to increase their involvement in the generation of research ideas, 'ground truthing' research ideas and in modifying and adapting adoption products and extension messages for more successful and broader industry application.
- It appears that R&D into sheep reproduction has been overly focussed on identifying and filling knowledge gaps rather than clearly defining problems at the farm level that need to be solved, and identifying what the best opportunities are for practically (and profitably) solving those issues.
- Stakeholders identified a range of current gaps in sheep reproduction extension relating to: producer awareness of R&D outcomes and extension programs and activities; effective producer engagement to facilitate participation in extension programs and activities; capacity and capability of service providers to extend sheep reproduction messages; adoption of best practice management strategies for sheep reproduction by producers; translation of R&D outcomes to practical extension messages and adoptable changes on farms (research to practice); repeatability of best practice management outcomes on farms and producer dis-adoption; and range of extension products and tools.

Industry Collaboration on Sheep Reproduction RD&E

- Since commencement of the SRRIP, 8% of all industry investment and 10% of all projects on sheep reproduction have involved collaboration between MLA and AWI, and 59% of all projects have involved collaboration between multiple delivery organisations.
- Although the amount of formal collaboration between MLA and AWI was viewed by most stakeholders as being less than ideal, the review found that considerable informal collaboration occurs via regular communication between MLA and AWI sheep reproduction management personnel.
- Stakeholder feedback indicates a need for greater sharing of information regarding the status of what R&D is being undertaken across industry, regardless of funding source.
- Stakeholder feedback also indicates concern that a disproportionate amount of MLA and AWI sheep reproduction R&D funding is provided to a relatively small proportion of delivery organisations and individuals which limits the potential for maintaining and building R&D capacity and capability, and increases risk.
- Only five non-producer commercial businesses have been involved in delivery of sheep reproduction RD&E in 8% of projects since mid-2012, and there have only been three international organisations involved in project delivery over the same period of time. Stakeholder feedback suggests that there is an opportunity to increase engagement with both the commercial sector and international R&D providers to add value to sheep reproduction outcomes in Australia,

and also with the education sector (secondary and tertiary) to engage with and influence the next generation of producers as early as possible.

- There may be opportunities for attracting funding for sheep reproduction RD&E from environmental funding sources where RD&E outcomes that contribute to increasing environmental stewardship from sheep production systems can be demonstrated.
- There is an opportunity to minimise the financial costs and the additional time associated with achieving collaboration while maximising the utility of project outcomes for producers by:
    - Simplifying the process of project contracting between RDCs; and
    - Clarifying the objectives of IP and simplifying the process of determining IP arrangements.
- To facilitate more effective collaboration in the future there is a need to further incentivise service providers to collaborate with one another and with MLA and AWI, and to create a more strategic approach to decision making by MLA and AWI around co-funding of sheep reproduction projects.
- While the vast majority of stakeholders indicated a desire for more industry collaboration on the issue of sheep reproduction in the future, many also acknowledged that there are various challenges associated with achieving successful collaboration. Stakeholders also expressed mixed views regarding collaboration between multiple delivery partners on individual projects.

Recommendations

The review process identified a range of current gaps in sheep reproduction RD&E in addition to opportunities for improving industry collaboration on sheep reproduction in the future. A series of recommendations has been provided for addressing these gaps and for capitalising on identified opportunities. A summary of these recommendations is provided below:

Investment Planning

- A new National Sheep Reproduction RD&E Investment Plan be developed for commencement in 2020/21. The next version of the plan should:
    - Involve broad industry consultation across all relevant sectors and organisations;
    - Establish a clear purpose for the plan including industry outcomes that reflect all stakeholder needs;
    - Establish national objectives and KPI targets that align with the objectives of other relevant industry strategic plans;
    - Be developed/co-ordinated by an independent person/persons (e.g. RDCs/external provider not linked to delivery);
    - Involve utilisation of an agreed standard process for evaluating the potential economic benefits from alternative project investments;
    - Be accompanied by an operational plan for delivery and a monitoring and evaluation framework for assessing delivery progress against KPIs and to modify the direction of the plan if deemed necessary;
    - Be implemented under the direction of an industry representative steering committee of organisations and sectors committed to achieving the intended outcomes of the plan; and
    - Establish appropriate governance and accountability structures and processes for implementation, monitoring and evaluation.

- Establish formal commitment to implementation of a new SRRIP through a binding partnership agreement with all relevant partners to commit funds and resources to implementation of the plan for its duration.

- MLA and AWI to review their level of relative investment in sheep reproduction RD&E in light of the perceived misalignment between the importance of the issue of lamb survival, particularly from an animal welfare perspective, relative to the proportion of RD&E funds invested in addressing the issue.

- MLA and AWI to explore the scope for increasing funding allocated to key areas of sheep reproduction RD&E, such as increasing ewe and lamb survival and increasing the reproductive efficiency of ewe lambs, on the grounds that outcomes from these areas of RD&E also contribute to organisational objectives for environmental and animal health and welfare outcomes.

- Industry to define and report on the impact of improving ewe reproductive rate on reducing the carbon footprint per unit of product output (wool and lamb). Identifying and promoting these benefits will add to the value proposition for increased investment in sheep reproduction in coming years to reduce the carbon footprint of both wool and lamb production, and to contribute to the 2030 goal of carbon neutral red meat production.

- Greater recognition by funding bodies of the trade-off between increasing ewe fertility and lower lamb survival among the additional lambs born, with subsequent greater clarity around the required balance between these two objectives at a strategic level to better inform and guide decision making for project investments.

- MLA and AWI to work together to develop a consistent process for classifying, valuing and reporting in-kind contributions from delivery partners.

Monitoring and Evaluation

- MLA and AWI to invest in the development of consistent monitoring, evaluation and review (MER) frameworks to monitor performance of projects, in addition to measuring impact and adoption that feeds into continuous improvement processes by:

    - Investing in the development and implementation of consistent MER for all extension projects/programs that reports on the success of the event/activity in terms of participation, in addition to adoption and impact of the project/program on farm.

    - Where possible, and particularly for larger projects, invest in processes to collect and validate impact data from producers over multiple seasons to more accurately assess long term impact.

    - Project/program evaluations be conducted by independent providers outside of project/program development and delivery activities.

    - Sharing evaluation results with all project stakeholders including delivery staff, participants and other interested stakeholders.

- In setting KPI targets for improvements in sheep reproduction efficiency in all industry strategic plans:

  - Include a range of KPIs which reflect the specific objectives of RD&E investments for increasing sheep reproduction efficiency.
  - Ensure that there is data available to assess performance against all KPIs identified in strategic plans.
  - If no data is currently available to assess performance against a KPI, either remove the KPI from the strategic plan, or identify a means of obtaining the data required to measure change.
  - Acknowledgement be given and/or provisions made for the influence of seasonal variation on the ability to achieve targets.

- Establish and maintain a national database of key performance indicator data for monitoring changes in sheep reproduction efficiency by:

  - Investing in the adaption of one national data collection process to enable reporting against all key statistics for tracking progress against sheep reproduction strategic objectives;
  - Developing a process for ensuring that all extension/adoption pathways establish and monitor key metrics for measuring engagement, adoption and impact that can be related to national data; and
  - Ensuring that data used for reporting progress feeds into continuous improvement and evaluation processes so that results are informing delivery and investments are adjusted accordingly.

- Given that climate variability is likely to increase in the future, MLA and AWI to consider investigating methods for modelling the impact of season on sheep reproduction rate in an effort to account for at least some of the seasonal influences on measured reproduction outcomes. This information may also assist with communication of efforts to improve animal welfare outcomes with consumers and the challenges associated with increasing lamb survival on farms.

Delivery and Collaboration

- MLA and AWI to engage with sheep consultants who are promoting messages which are potentially counterproductive to the objective of increasing lamb survival, and involve them in a process of creating greater clarity and information around the profitability or otherwise of improving ewe and lamb survival, as opposed to increasing ewe fertility, in a range of wool producing systems.

- MLA to review and update the content of the Business EDGE workshop notes to ensure that it aligns with industry strategic objectives for lamb survival.

- Identify and segment the target audience for each adoption product and determine how best to engage each target audience and how that engagement will be monitored and evaluated.

- Increase the proportion of investment allocated to developing and extending research outcomes to enable more next users (e.g. consultants) and end users to benefit by:

    - Investing in a curated database to store all sheep reproduction RD&E project reports, including contact details for each project to enable follow up of outcomes. This database needs to be easily searchable and accessible to all stakeholders. Investment needs to cover maintenance and communication of content widely to improve awareness across the industry.
    - Prioritising allocation of sufficient resources to ensure that an adoption pathway is established for all extension and adoption messages at the beginning of a project utilising input from extension specialists.
    - Reviewing R&D projects with adoptable outcomes by next users to determine extension/adoption messages, extension adoption pathway, target audiences (next users and end users) and what additional work is required to ensure that information/messages are:

        * Locally relevant
        * Economically viable
        * Applicable to the spectrum of different sheep business types i.e. Merino self-replacing, non-Merino terminal flocks etc, different lambing times, specialist versus mixed enterprise sheep farms, intensive versus extensive production systems.

- Investment be made in designing extension activities to achieve adoption by the target audiences, including next users (e.g. consultants), that aims to solve well defined on-farm problems:

    - Each R&D adoptable output (product) adoption pathway includes the extension method, definition of target audience (next and end users) and incorporates capacity and capability building of the delivery network.
    - Adoption programs explore and define the required outcome from the end user perspective before promoting the details of the program methodology.
    - Invest in promotion and marketing of extension programs beyond word of mouth and traditional forms of advertising. This includes analysing participation data to inform approaches.

- MLA and AWI to engage with research providers to investigate opportunities for provision of a centralised source of information on the status of sheep reproduction R&D regardless of funding source.

- MLA and AWI to review the potential for increasing the breadth of engagement with service delivery providers with the objective of ensuring that all relevant sectors are engaged, and to ensure the sustainability of capacity and capability within and across organisations involved in sheep reproduction R&D delivery.

- MLA and AWI to actively identify and explore potential opportunities to engage more with the education sector (secondary and tertiary) to establish a relationship with and influence the next generation of producers as early as possible, and with commercial enterprises and international RD&E providers to partner with for sheep reproduction RD&E.

- MLA and AWI to identify and explore potential opportunities for collaboration with organisations and programs with environmental objectives, such as Landcare, Catchment Management Authorities, Land and Water Australia and corporate businesses, in areas of sheep reproduction RD&E where environmental benefits can be demonstrated.

- MLA and AWI to establish agreed processes and principles for project management and intellectual property arrangements for all projects delivered as part of the National Sheep Reproduction RD&E Investment Plan:

    - MLA and AWI to develop a consistent framework for defining terms and conditions for co-funded project investments as opposed to terms and conditions being developed and agreed to on a project by project basis. This may involve differentiating the process required depending on the type of investment, particularly where project outcomes involve commercialisation of a product or process compared to more knowledge-based project outcomes.

    - MLA and AWI to develop a set of key principles around the objectives of IP arrangements for project investments, to communicate these principles to funding partners and utilise them to guide development of IP arrangements at the project level. Suggested guiding principles could include:

        * IP arrangements should enable maximum utility of project outcomes for industry;
        * Delivery partners who do not provide funding to the project (either in-kind or cash) require a simple licensing agreement to utilise any IP generated from the project which is not publicly available beyond the terms of the project contract;
        * IP arrangements should ensure fair treatment of all funding partners in division of ownership of IP generated by project activities; and
        * IP arrangements should limit background and third-party IP to the minimum required for the project to simplify contracting processes.

- Increase the potential benefits from collaboration by increasing the incentive for industry partners to co-invest and share ideas, and provide a more structured framework for decision making around collaboration at a strategic level by:

    - Establishing large programs of work which extend over the period of the SRRIP and which align with the priorities identified in the SRRIP;

    - Identifying strategic partners who are willing and able to commit co-funding for each program area under agreed arrangements (via the Strategic Sheep Reproduction Partnership process currently in motion) to deliver required outcomes according to SRRIP KPIs;

    - Engage with relevant strategic partners to develop projects to address the key priority areas within each program;

    - Allocate approved project delivery activities within each program to strategic partners according to project requirements, co-funding committed and availability of relevant skills, knowledge, infrastructure and equipment within partner organisations. The emphasis should be on collaboration where this creates benefits, but also involve a willingness to

make strategic decisions not to collaborate in instances where it is not considered cost effective to do so;

- Where required, engage service providers outside of the strategic partnership where additional skills, knowledge or experience for achievement of project outcomes is considered to be necessary;
- In addition to commissioned projects developed to align with achievement of SRRIP objectives, a portion of total available funding be committed to an open-call process for projects to facilitate generation of new ideas and research directions; and
- At the RDC level, based on available funding, MLA and AWI identify their priority areas for funding allocation, and where these areas cross-over, co-funding arrangements are implemented. This may be at a program investment level, or if more delineation of investment areas is required, at the project level.

Further details for these recommendations are provided in Appendix A.

List of Terms and Acronyms

ABARES: Australian Bureau of Agricultural Resource Economics and Sciences

ABS: Australian Bureau of Statistics

AGBU: Animal Genetics and Breeding Unit joint venture between the New South Wales Department of Primary Industries (DPI) and University of New England (UNE)

AHA: Animal Health Australia

AI: Artificial Insemination

ASBV/BV: Australian Sheep Breeding Value/Breeding Value

AWI: Australian Wool Innovation

BOM: Bureau of Meteorology

CMA: Catchment Management Authority

CS: Condition Score

CSIRO: Commonwealth Scientific and Industrial Research Organisation

DJPR: Victorian Department of Jobs, Precincts and Regions

DPIRD: Department of Primary Industries and Regional Development (Western Australia)

FOO: Feed on Offer

IP: Intellectual Property

LWA: Land and Water Australia

MER Cycle: Monitoring, Evaluation and Review Cycle

MISP: Meat Industry Strategic Plan 2020

MLA: Meat and Livestock Australia

NAWRDE: National Animal Welfare RD&E Strategy 2017

NLW/NLB: Number of Lambs Weaned/Number of Lambs Born

PIRSA/SARDI: South Australian Department of Primary Industries and Regions/South Australian Research and Development Institute

RDC: Research and Development Corporation

SALRC: Southern Australian Livestock Research Council

SISP: Sheepmeat Industry Strategic Plan 2015-2020

SPA: Sheep Producers Australia

SRRIP: Sheep Reproduction RD&E Investment Plan 2012-2017

WALRC: Western Australian Livestock Research Council

WIRNS: Wool Industry National RD&E Strategy 2018-2022

WPA: WoolProducers Australia

Table of Contents

1.0 Background

Improving lamb survivability on-farm is a key priority for Australian sheep and wool producers. The peak industry councils, WoolProducers Australia (WPA) and Sheep Producers Australia (SPA), Animal Health Australia (AHA) and the industry research and development corporations (RDCs), Meat and Livestock Australia (MLA) and Australian Wool Innovation (AWI), share a commitment to increasing lamb survivability through industry research, development, extension (RD&E) and adoption of relevant on-farm management practices. This commitment was formalised through a process of broad industry consultation across the sheep meat and wool industry sectors and the subsequent development of the Sheep Reproduction RD&E Investment Plan 2012-2017 (SRRIP) (Appendix B).

Given that the delivery period for this plan is complete, and a recent stock take of ongoing research, development and extension projects has been undertaken, the industry is now seeking to develop new strategies and initiatives to further improve lamb survival outcomes. As a precursor to this process, Beattie Consulting Services and Inspiring Excellence were engaged to provide an independent review of the benefits, costs and impacts of current and recently completed RD&E activities in sheep reproduction and lamb survival against key industry performance targets, to identify remaining gaps in RD&E and to assess the effectiveness of industry collaboration on sheep reproduction.

2.0 Terms of Reference

2.1 Project Objectives

The objectives of the impact assessment were:

1. Review and assess completed and ongoing industry projects and initiatives against the objectives of the SRRIP strategy, the Wool Industry National RD&E Strategy 2018-2022 (WIRNS), the Meat Industry Strategic Plan 2020 (MISP), the Sheepmeat Industry Strategic Plan 2015-2020 (SISP), the National Animal Welfare RD&E Strategy (NAWRDE) and the Sheep CRC. The criteria include consistency across strategies in objectives and targets.

2. Assess, define and make recommendations for future industry collaborations. The criteria targets efficient use of funds such as the structures for project management of co-invested projects that reduce duplication, intellectual property (IP) arrangements between the RDCs that benefit wool and meat levy payers, shared communication, leverage of resources (cash and in kind) and evaluation of investment.

3. Assess and define the predicted economic impact of investments made to date, based on assumptions on adoption, on-farm productivity benefits and the cost of implementation. This is to be based on the MLA output (product) based impact assessment framework.

4. Provide a detailed assessment of any remaining research and/or adoption gaps, and provide a series of recommendations for RD&A investments based on an economic impact assessment of the key priority areas and potential opportunities for delivering further industry impact.

3.0 Methodology

3.1 Review and Assessment of Projects

A total of 120 sheep reproduction RD&E projects were reviewed and categorised based on the following criteria:

- Alignment with the SRRIP investment pillars
- Alignment with the SRRIP investment timeframe (2012-2017)
- Alignment of project objectives with strategic objectives of the WIRNS, the MISP, the SISP, the NAWRDE and the Sheep CRC
- Type of project investment:

    - Category 1: The project creates or contributes to an existing or new output (product) with directly attributable adoption outcomes and adoption related productivity impacts.
    - Category 2: The project delivers tools and enabler type outputs that do not directly deliver attributable impact, but are necessary to support other products such as extension programs. Examples include investigation of R&D opportunities, investigating industry issues, benchmarking, websites or software tools.
    - Category 3: The project does not deliver an output (product) with attributable adoption outcomes or impacts, but should be funded for other reasons. For example, 'blue sky' or Horizon 3 research.

A summary of the areas of sheep reproduction RD&E invested in since the commencement of the SRRIP is provided in Appendix C.

3.2 Impact Assessment of Relevant Project Investments

The evaluation utilised the MLA Path to Impact Assessment Framework involving a 'bottom up' assessment approach to capture adoption outcomes and productivity impacts at a product (output) level and then aggregated outputs to determine the overall impact of relevant project investments during the SRRIP delivery period (2012-2017) over a 25-year period from 2012/13 to 2036/37.

Projects in Category 1 which were contracted during the SRRIP investment timeframe (2012/13 to 2016/2017) were assessed to review all available data for each product with an associated identification of gaps in availability of required data (both impact and adoption gaps). Where possible, these information gaps were filled via a combination of the following processes:

- Wider literature review of relevant external data.
- Consultation with industry researchers, project managers and subject experts.
- Phone interview data conducted with participating producers (adoption products) as part of previous impact assessments.
- Consultants' own knowledge, experience and network of resources.

The approach in undertaking this assessment was to evaluate the benefits of RD&E investment in sheep reproduction in terms of expected future productivity of producers in a 'with investment' scenario, compared to the productivity of the same businesses in a 'without investment', or counterfactual scenario. The costs of the investment were the expenditure from MLA and AWI in addition to delivery partner co-investment and in-kind dollars.

The difference between the benefits for the 'with investment' and 'without investment' scenarios were valued over the 25-year period, and this net benefit stream was then matched with annual RD&E investment. All dollars were expressed in 2020-dollar terms using the CPI and all costs and benefits were discounted or compounded to present value terms using a discount rate of 5% in alignment with the Council of Rural Research and Development Corporations guidelines. Results are presented in terms of Net Present Value (NPV), being the difference between the present value of benefits and the present value of costs, Benefit Cost Ratio (B:C ratio), being the ratio of the present value of benefits to the present value of costs, and Internal Rate of Return (IRR), being the break-even discount rate. A sensitivity analysis of the impact assessment was also undertaken.

3.3 Identification of RD&E Gaps and Assessment of Industry Collaboration

An extensive stakeholder engagement process was undertaken to obtain industry feedback regarding views on RD&E gaps in sheep reproduction and the effectiveness of industry collaboration for delivery of the SRRIP. One-hundred individual stakeholders were engaged during the review process, with 51 stakeholders interviewed over the phone, and 49 producers engaged via an online survey. A list of organisations and sectors represented is provided in Appendix D. The stakeholders engaged were identified by the project steering committee (MLA, AWI and AHA) in consultation with SPA and WPA. A written submission was also provided by SPA. Figure 1 presents the proportion of each type of organisation represented by phone interview participants.

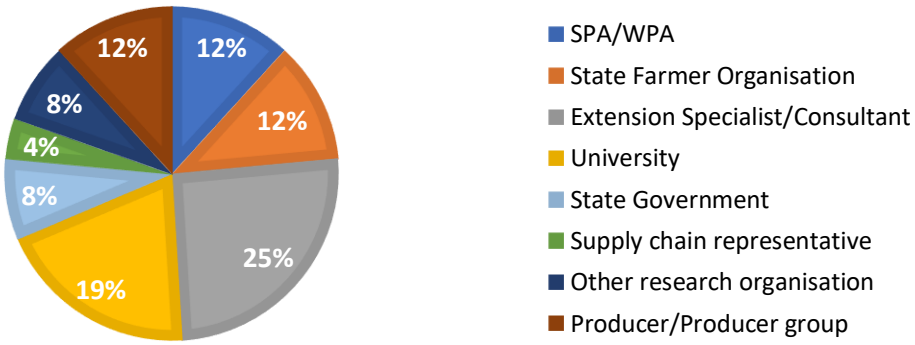


Figure 1: Proportion of phone interview participants representing each industry sector engaged during the review process (n=51)

The online survey was distributed to producers via SPA, WPA and various state farmer organisations (Appendix D). Figure 2 presents the state of origin for the producers who completed the online survey and Figure 3 presents the representation of breed types among survey respondents.

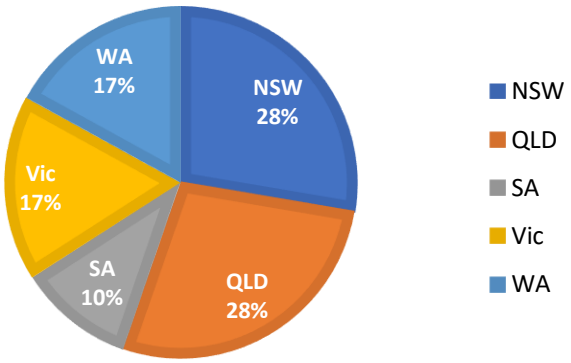


Figure 2: Proportion of online producer survey participants representing each state (n=49)

The majority of respondents ran Merino ewes, with just over half running a straight Merino enterprise, 10% running Merino ewes over non-Merino rams and around 20% running a mixture of Merino and non-Merino ram breeds over Merino ewes.

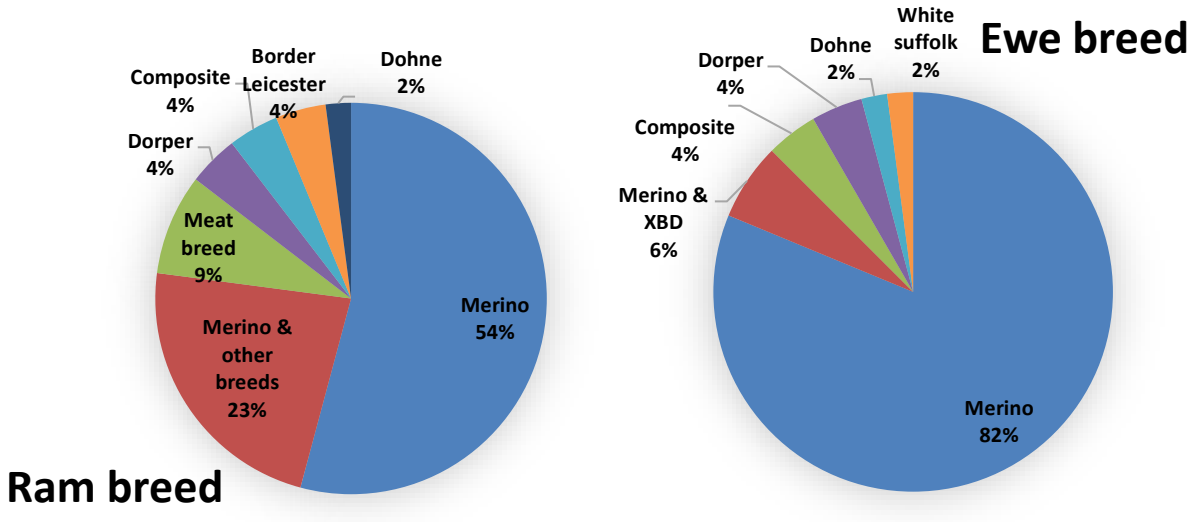


Figure 3: Representation of breed types among producer online survey participants (n=49)

The number of ewes joined per business ranged from zero, due to drought, up to 8,500, with a median of 2,334 ewes per business.

4.0 Industry Strategic Alignment with the SRRIP

4.1 Sheep Reproduction Key Performance Indicators

Table 1 presents the sheep reproduction key performance indicator (KPI) targets for the SRRIP and for each of the relevant industry strategic plans.

Table 1: Sheep reproduction key performance indicators aligned to industry strategy

Strategy (Timeframe)	Reproduction Rate & Lamb Survival KPI Targets	Mortality KPI Targets	Ewe Lamb Joining KPI Targets	Adoption KPI Targets
SRRIP (2012-2017)	Increase net reproduction rate by 10 percentage points (annual increase of 2%)	None	None	None
SISP (2015-2020)	Increase lamb marking rate by 5 percentage points (annual increase of 1%)	Decrease ewe mortality by 1 percentage point by 2020 (Annual decrease of 0.2%)	None	None
MISP (2015-2020)	None	None	None	None
WIRNS (2018-2022)	Increase lamb marking rate by 0.5 percentage points per year to 2030 Merino lamb survival rates increase by 0.2 percentage points per year to 2030	Adult Merino sheep mortality is reduced by 0.1 percentage points per year to 2030	Proportion of hogget ewes* mated increases by 0.5% pa from 10% to 17.5% by 2030	25% of Merino ewes are managed using Lifetime Ewe Management recommendations by 2022 Number of Merino ewes scanned and differentially managed increases from 25% to 34% by 2022
NAWRDE (2017)	Demonstration of continuous improvement in animal welfare		N/A	Education, training and extension strategies are developed and implemented to deliver animal welfare R & D outcomes.

* Interpreted to mean ewe lambs.

The only indicator of success for the SRRIP is lamb marking percentage as a proxy for number of lambs weaned per ewe. While lamb marking rate is a useful indicator of change over time in sheep reproduction efficiency, there are limitations to its use as a single indicator of success. Relative to the types of sheep reproduction project investments, lamb marking rate as a single indicator of success is limited in that:

- It does not provide any information about how the components of reproductive rate have changed i.e. how lamb survival has changed relative to conception rate and early embryo losses.
- It does not account for changes in ewe mortality rates.
- It does not account for the influence of any changes in the proportion of ewe lambs joined (lower marking rates), nor provide any information on changes in ewe lamb reproduction outcomes.
- It does not differentiate between targets for different breeding systems (i.e. Merino versus non-Merino).
- It is very susceptible to seasonal influences between years.

Finding 1: *As a single indicator for measuring change in sheep reproduction efficiency over time, lamb marking rate has several key limitations.*

While lamb marking rate as a single measure of success does have limitations, it is the only sheep reproduction indicator for which national time series data is available. With the exception of the WIRNS target relating to Lifetime Ewe Management (LTEM), there is no national time series data available to measure success against any of the other numerical key performance indicators identified in Table 1.

Finding 2: *With the exception of the WIRNS target relating to Lifetime Ewe Management, other than lamb marking rate, there is no national time series data available to measure success against any of the other numerical key performance indicators for sheep reproduction identified in industry strategic plans.*

Recommendation 1: *In setting KPI targets for improvements in sheep reproduction efficiency in industry strategic plans:*

- *Include a range of KPIs which reflect the specific objectives of RD&E investments for increasing sheep reproduction efficiency (e.g. ewe mortality, ewe lamb conception rates, ewe fertility and lamb survival).*
- *Ensure that there is data available to assess performance against all KPIs identified in strategic plans.*
- *If no data is currently available to assess performance against a KPI, either remove the KPI from the strategic plan, or identify a means of obtaining the data required to measure change.*
- *Acknowledgement be given and/or provisions made for the influence of seasonal variation on the ability to achieve targets.*

4.2 Industry Strategic Alignment with the SRRIP

Figure 4 presents the alignment between expected outcomes from the SRRIP and objectives of the MISP, SISP, WIRNS, NAWRDE and Sheep CRC.

Figure 4: Alignment between the SRRIP and the objectives of the MISP, SISP, WIRNS and NAWRDE

Each of the 120 projects assessed during the review process has been mapped to relevant MISP and SISP imperatives, WIRNS and Sheep CRC3 programs, and NAWRDE themes. Appendix E provides further details regarding which imperatives for each strategic plan/program align to each of the SRRIP pillars and the proportion of all sheep reproduction projects reviewed which align with each strategic plan/program.

5.0 Value Proposition for Increasing Sheep Reproduction Efficiency

During the review process, stakeholders identified five key industry benefits from increasing ewe reproduction rate (Figure 5).

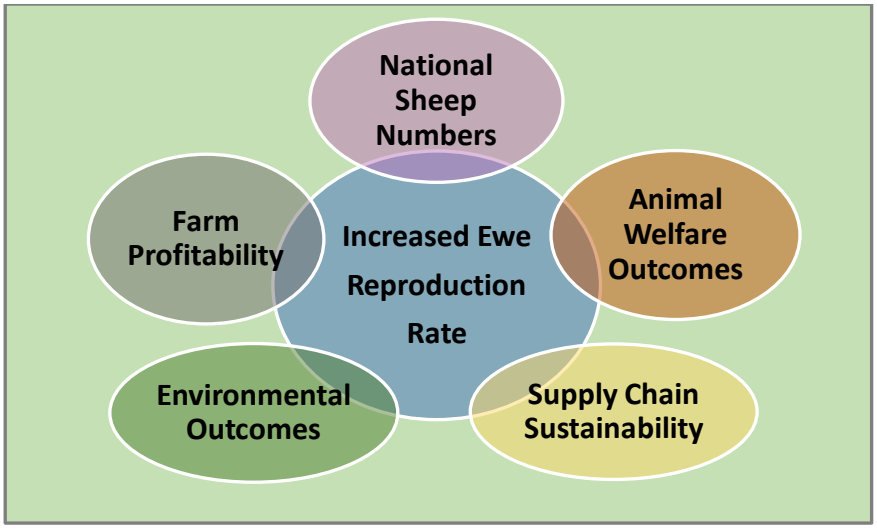


Figure 5: Identified industry benefits of increased ewe reproduction rate

5.1 Sheep Numbers and Supply Chain Sustainability

Sheep numbers in Australia have declined significantly over the past 30 years or so (Figure 6), and have been predicted by MLA to decline further in 2020, to around 63.7 million head, on the back of drought conditions that have forced many producers to sell off core breeding stock.

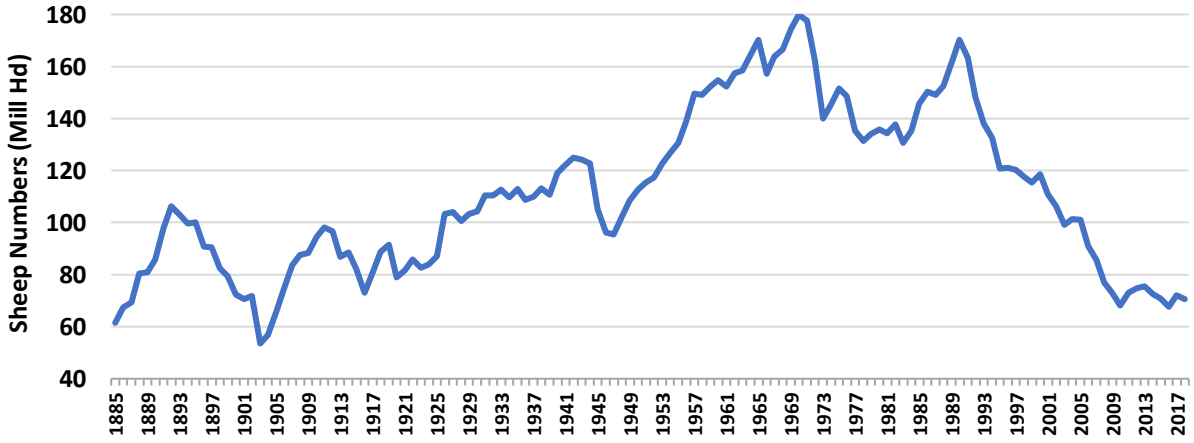


Figure 6: Australian sheep numbers over time (Source: ABS)

At a macro level, increasing the size of the national sheep flock is an important objective in terms of ensuring the sustainability of the wool and sheep meat supply chains, and increasing levy payer funds available for investment in RD&E and marketing. The stakeholder consultation process for this review indicates that many stakeholders feel that increasing lamb survival will be a key component in rapidly increasing the size of the national flock.

"*To ensure consistency of lamb, mutton and wool supply and sustain the national breeding flock, continued improvements in lamb marking rates at the farm level are necessary*" **SPA, 2020**

While the collapse of the Reserve Price Scheme had a significant impact on sheep numbers during the 1990's, other factors have driven the decline into the 20th century. Figure 7 presents ABARES data on

the number of farm businesses running sheep and the average number of sheep per business. This data indicates that a declining number of farm businesses running sheep, rather than a decline in the number of sheep being run per business, has driven most of the decline in overall sheep numbers at a national level.

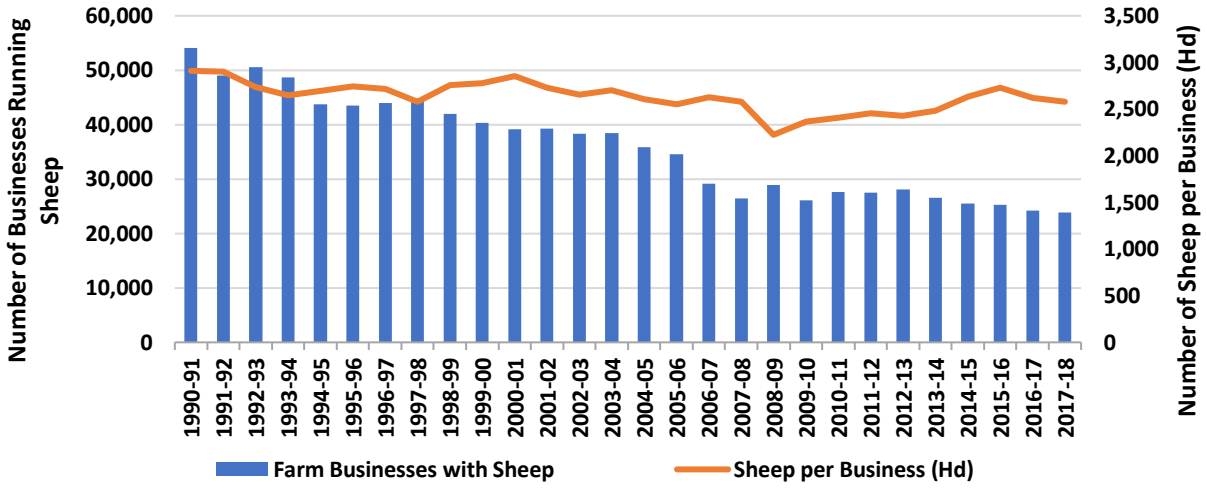


Figure 7: Changes in number of farm businesses with a sheep enterprise and number of sheep per business since 1990 (Source: ABARES Farm Surveys)

This downward trend in the number of farm businesses running sheep has been consistent across all states, however it should be noted that the number of farms running sheep in Victoria and Queensland (QLD) increased between 2016/17 and 2017/18.

It is suggested by the authors that the key reasons for the declining number of businesses running sheep flocks over the past 20 years include:

- Higher profitability of alternative enterprises
- Labour shortages (incl. shearers)
- Lower labour efficiency relative to cropping and cattle
- Prolonged periods of drought
- Wild dogs (QLD, southern New South Wales (NSW), northern Victoria)
- Ageing farmer population
- Consumer pressure regarding animal welfare (e.g. mulesing)
- Reported preference among the younger generation for cropping
- Ovine Johne's Disease

Since the early 1990s many farmers have substituted a sheep enterprise for cropping and/or beef. Figure 8 shows the changes in total cattle numbers and area cropped for cereals since 1990.

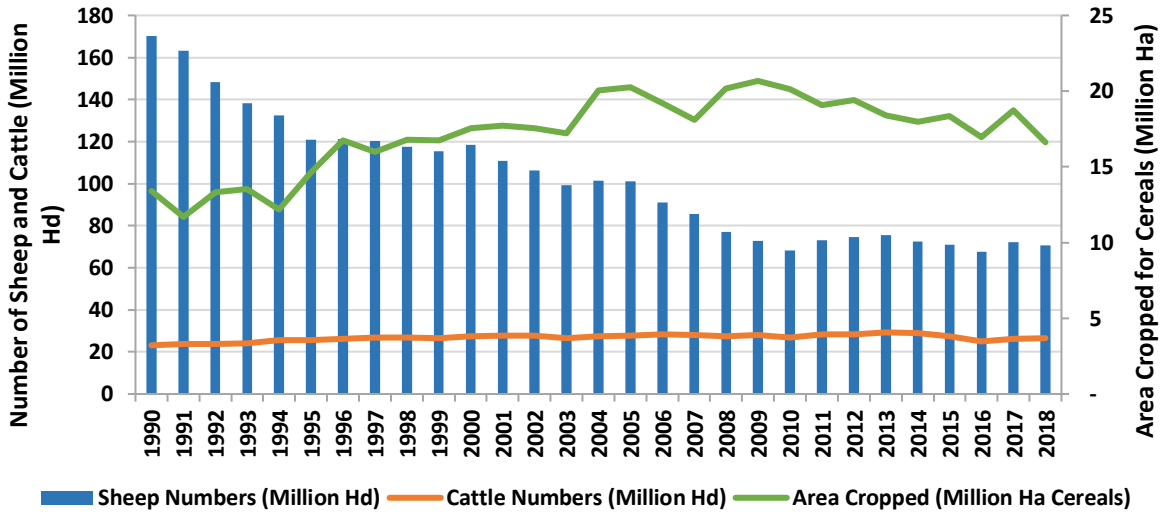


Figure 8: Changes in national cattle numbers, sheep numbers and area cropped for cereals since 1990 (Source: ABS Agricultural Commodities data)

Figure 8 also indicates that national sheep numbers have stabilised from around 2010 onwards, though have fallen over the previous two years due to high lamb and mutton prices driving higher slaughter rates and destocking in drought affected areas. It is suggested that opportunities for increasing sheep numbers over the next 5 to 10 years will include:

- Increasing stocking rates post drought in many areas
- Enterprise diversification in cropping systems to reduce risks associated with increased climate variability and herbicide resistance
- High lamb and sheep meat prices (land use change)
- Emerging opportunities in south central QLD post improved dog control fencing
- Higher wool prices to drive sustained flock building
- Development and extension of sheep labour saving technologies

The speed with which these opportunities may be realised will be driven by wool, lamb and mutton prices, the availability of sheep for restocking (both within existing flocks and for purchase), the impact of wild dogs in emerging sheep growth areas in QLD, labour availability, availability and adoption of sheep management labour saving technology, and availability of capital to fund sheep infrastructure for growth areas. While high lamb and sheep meat prices may lead to some land use change into sheep, sustained high prices will also result in strong sheep slaughter rates which will hinder growth in sheep numbers in the short term.

Thus, while increasing the size of the national sheep flock is a priority at a national level, it is not necessarily aligned with decision making at an individual farm level. Increasing reproductive rate at the farm level will not lead to increases in the size of the national flock unless producers decide to increase stocking rate (as opposed to selling surplus stock), or to substitute land use. Increasing reproduction rate may, however, assist the speed with which those wishing to increase numbers are able to do so. It is also important to consider that as sheep numbers have declined over time, the lower product supply has driven prices higher (Figure 9), which has been to the advantage of those remaining in the industry. An increase in the size of the national flock may therefore be counter to the profitability of individual sheep producers.

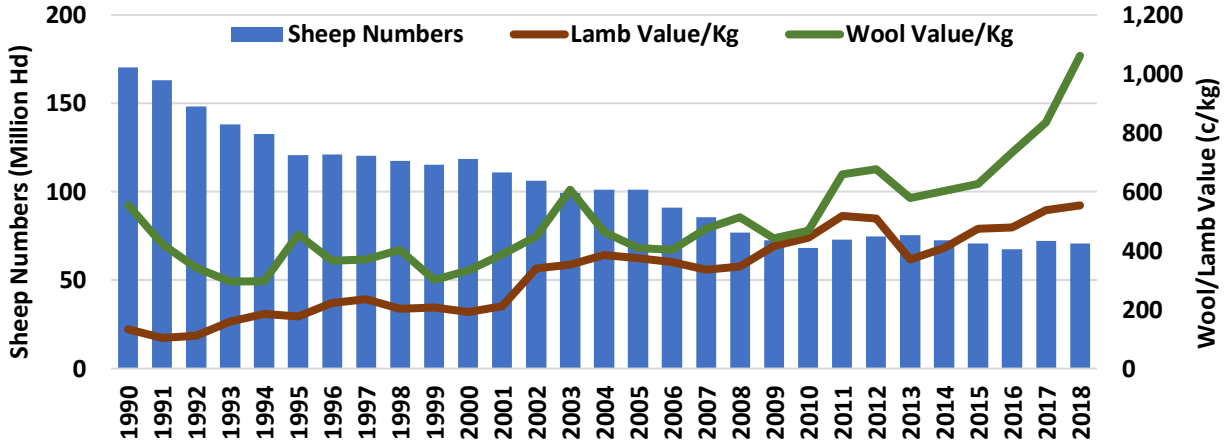


Figure 9: National flock compared to product prices in real terms received by farmers (Source: ABS/ ABARES)

Finding 3: *While increasing the size of the national sheep flock is a priority at a national level, it is not necessarily a priority for individual producers. At the farm level, increasing the size of the national flock is not an objective that influences decision making, and increasing reproductive rate will not necessarily lead to increases in the size of the national flock.*

5.2 Animal Welfare and Environmental Sustainability

Over recent years consumer expectations have increased dramatically for standards of animal welfare and environmental sustainability of food and fibre production systems. The issue of lamb survival is at the forefront of current industry efforts to improve animal welfare outcomes for sheep and wool production systems. While environmental impacts have less focus, there are none-the-less opportunities to reduce the carbon footprint for wool and sheep meat production to proactively address consumer concerns.

5.2.1 Animal Welfare

Increasing animal welfare results from increasing lamb survival and reducing ewe mortality, however increasing reproductive rate also involves increasing ewe fertility, which typically involves a decrease in lamb survival associated with greater numbers of multiple births. Table 2 presents data from both Australia and internationally for lamb survival by birth type. It should be noted that the vast majority of lambs in Australia are lambed in extensive conditions, with very few commercial enterprises lambing in sheds. As such, the data reported for Australian intensive management conditions only represents long term average data for two commercial farm business for approximately 1,600 ewes in total.

Table 2: Reported lamb survival data for Australia and internationally by birth type

	Extensive Management Conditions			Intensive Management Conditions		
	Singles	Twins	Triplets	Singles	Twins	Triplets
Australia	84% - 90%	67% - 72%	61%	90% - 96%	85% - 96%	74% - 86%
International	80% - 93%	73% - 87%	50% - 78%	88% - 94%	86% - 94%	75% - 93%

Source: Refer Appendix F

The sources for these datasets are provided in further detail in Appendix F, however it is important to note that they are not directly comparable as they involve different methods of calculating lamb survival, different breeds and different versions of 'extensive and intensive' management systems. However, what this data does illustrate is that:

- There is variation in the methods used to measure and report lamb survival. In terms of animal welfare, the most relevant measure is lambs weaned/marked to lambs presenting at birth (dead and alive), however this measure is difficult to achieve accurately in the field, particularly in the typically extensive commercial operations in Australia.

- An easier measure to define is losses between scanning and weaning/marking, however this information is less useful to measure improvements in animal welfare over time.

- Lamb survival falls as ewe fecundity increases, particularly in extensive conditions. In intensive conditions the gap between single and twin lamb survival is minor, however triplet losses are typically 10-25% higher than for twins and singles. Thus, from an animal welfare perspective, increasing ewe fecundity is likely to be counterproductive to increasing lamb survival in extensive conditions.

- There are opportunities to increase lamb survival considerably by increasing the intensity of management, however the cost of achieving these gains is also higher. Thus, there will be an optimal level of lamb survival for individual producers based on profitability as the key decision-making criteria.

There does not appear to be sufficient formal recognition of the trade-off between increasing ewe fertility and decreasing lamb survival among the additional lambs born in terms of their contribution to the overall objectives of RD&E into sheep reproduction. If the priority is to increase lamb survival, then investment in increasing ewe fertility is counter to this objective due to increased mortality in multiple birth lambs, however if it is recognised that a more balanced approach is needed, then that balance needs to be more clearly defined and articulated at a strategic level to better inform investment decision making at the project level.

Finding 4: *Increasing animal welfare by increasing lamb survival is a high priority for the industry, however there is a conflict between increasing ewe fertility as a priority and the lower lamb survival of twin and triplet lambs in the extensive conditions on Australian farms.*

Recommendation 2: *Greater recognition by funding bodies of the trade-off between increasing ewe fertility and lower lamb survival among the additional lambs born, with subsequent greater clarity around the required balance between these two objectives at a strategic level to better inform and guide decision making for project investments.*

5.2.2 Carbon Footprint

Over recent years there has been an increasing community call for consumers to decrease red meat consumption amidst concern regarding the impact of red meat production on greenhouse gas (GHG) emissions. In response to this community concern, the red meat industry has set a goal of carbon neutral meat production by 2030. According to a meta-analysis of available data on agricultural product carbon

emissions (Clune *et al.*, 2016), sheep meat production generates a considerably larger carbon footprint than both chicken and pork, and a similar footprint to that for beef (Figure 10).

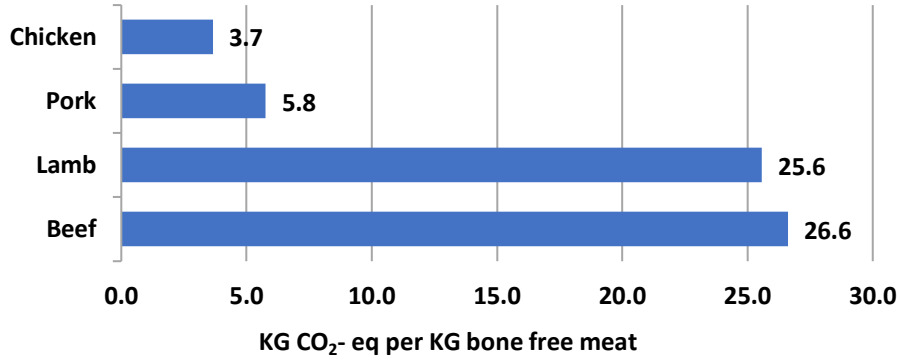


Figure 10: Emissions per unit of protein output for a range of livestock species

The carbon footprint for wool production was reported by Brock *et al.* (2013) as 24.9 kg $CO_{2\text{-eq}}$ per kilogram of greasy 19-micron wool produced in the Yass Region of the Southern Tablelands of New South Wales. Weidemann *et al.* (2015) reported GHG emissions based on biophysical allocation of wool protein to wool of 10–12 kg $CO_{2\text{-eq}}$ per kilogram of wool across four case study farms. Reported emissions increased to 24–38 kg $CO_{2\text{-eq}}$ per kilogram of wool when biophysical allocation method included a proportion of sheep maintenance requirements allocated to wool production. It is evident from research into the carbon footprint associated with wool production that it is very sensitive to the method utilised to allocate resource use between wool and meat production for various system types (Cottle and Cowie, 2016).

Research has identified that in sheep production systems, the key opportunities for reducing the carbon footprint per unit of product output is to increase the reproductive rate per ewe, to join ewe lambs (in self-replacing systems) and to decrease lamb turn-off time (Jones A., 2014). It was identified that the most important opportunity to decrease carbon footprint is by improving ewe nutrition to increase lamb survival. It may therefore be useful for industry to invest in a standard process for measuring and reporting on the impact of improving sheep reproduction outcomes on the carbon footprint per unit of product output (wool and lamb) to add value to the proposition for industry investment in improving sheep reproduction outcomes, in addition to enabling demonstration of progress to consumers if required.

Finding 5: *Increasing community calls for reducing red meat consumption amidst concerns around greenhouse gas emissions has prompted the red meat industry to set a target of carbon neutral meat production by 2030. Greater investment in increasing lamb survival and reproductive rate of ewe lambs are key opportunities to assist industry in meeting this target.*

Recommendation 3: *Industry to define and report on the impact of improving ewe reproductive rate on reducing the carbon footprint per unit of product output (wool and lamb). Identifying and promoting these benefits will add to the value proposition for increased investment in sheep reproduction in coming years to reduce the carbon footprint of both wool and lamb production, and to contribute to the 2030 goal of carbon neutral red meat production.*

5.3 Farm Profitability

Feedback from the stakeholder engagement process indicates that most consider that increasing ewe reproductive rate is likely to be profitable for sheep producers given the current high lamb prices. However, it was also identified that current extension programs lack the ability to provide that value proposition to individual producers for specific practice changes. This reduces the ability of individual producers to make informed decisions as to whether investment in improving sheep reproduction will be profitable for their business, will be more profitable than alternative uses of their time, energy and funds (including debt repayment), which practice changes provide the highest returns on investment and in what order of priority should investments be made.

There was concern expressed by some stakeholders regarding mixed messages from industry, and 'blanket' type messages being provided to producers regarding the profitability of investment in improving sheep reproduction. The major concern identified was an acceptance of a minimum level of reproductive performance for Merino ewes in systems where wool production is the priority. This type of messaging therefore creates a potential barrier to adoption among a group of producers who arguably achieve a relatively low level of lamb survival compared to most other sectors of the industry.

One view expressed during this review is that benchmarking data supports the message that flock fertility in a business focussed primarily on wool production is not one of the more important profit drivers in a self-replacing system. While this may be the case, benchmarking data does not indicate whether or not it is profitable at the margin to increase lamb survival, and producers who hear this message may well look no further at investing effort in increasing lamb survival as a consequence. It was also reported during this review that the overall message to producers is about optimising feed utilisation, and that there can be a significant cost in energy demands at high fecundity levels which is rarely valued appropriately. It was suggested that there is typically a high attribution of benefit and a low attribution of actual cost to any increase in flock fecundity. The MLA Business EDGE extension program provides producers with a similar message:

"Fertility is NOT a profit driver in a specialist wool-growing flock. This statement assumes that sufficient weaners are produced each year to maintain optimal flock structure, which is normally around a weaning rate of 70%. At first this statement can be hard to accept, but the explanation follows. Let's say your weaning rate from your 6,000 ewes is normally around 80%. However, this year it suddenly jumps to 90% and you have 600 more weaners than usual to manage. If you can absorb those weaners, without having to sell mature sheep to make room for them, you are under-stocked. The additional revenue from the extra weaners has come from a stocking rate effect, not a fertility effect. You could have achieved exactly the same result by purchasing the additional weaners. If your stocking rate is at or near optimum for your environment, you would have to sell mature sheep to make way for the additional weaners. This assumes you did not sell them as weaners, which is never a good decision. When you sell mature sheep, you lower your wool cut per hectare. Does the revenue from the extra weaners, when it comes, compensate for the lower wool per hectare revenue? That depends on the mutton price at the time and how valuable your wool is, but in broad terms, mostly no." **MLA Business Edge Notes**

"...don't be deceived into thinking that fertility matters much in a wool flock." **MLA Business Edge Notes**

This kind of messaging provides 'blanket' statements without supporting economic data to reflect the impact of changes in relative wool, lamb and feed prices, and for different production systems. More importantly, it appears that the specific issue of increasing lamb survival has been overlooked as being

a lower cost opportunity to increase profit given the sunk nutritional cost already invested in getting the lamb to the point of birth, and this messaging also makes no mention of the animal welfare benefits associated with increasing ewe and lamb survival.

Finding 6: *Some of the extension messages provided to producers, particularly wool producers running self-replacing Merino flocks, by both consultants and the MLA Business EDGE program, are potentially counterproductive to the industry objective of increasing lamb survival.*

Recommendation 4: *MLA and AWI to engage with sheep consultants who are promoting messages which are potentially counterproductive to the objective of increasing lamb survival, and involve them in a process of creating greater clarity and information around the profitability or otherwise of improving ewe and lamb survival, as opposed to increasing ewe fertility, in a range of wool producing systems. This may involve:*

- *Consultants participating as part of a demonstration on a client's farm to assess the impacts of practice changes to increase lamb survival.*
- *Working with consultants to develop economic methodologies and agreed valuations of input costs to more accurately assess the value proposition for increasing lamb survival across a range of wool producing systems.*

These processes may show negative economic returns from increasing lamb survival in some systems, but the outcome would be more informed decision making for all wool producers, including those for which it is profitable to increase lamb survival, and a greater awareness of lamb mortality as an animal welfare issue, its causes, its costs and alternatives for its prevention.

Recommendation 5: *MLA to review and update the content of the Business EDGE workshop notes to ensure that it aligns with industry strategic objectives for lamb survival by:*

- *Ensuring that messages are supported by economic data, including a transparent process for reporting of that economic data so that producers are able to insert their own values to assess profitability over time for their own businesses.*
- *Include clarity around the difference between increasing ewe fertility and increasing lamb survival as different objectives and potential sources of increased profitability.*
- *Include commentary on the value of increasing lamb survival from an animal welfare perspective regardless of marginal profits.*

There was the view expressed by one stakeholder during the review process that it is not the responsibility of individual farmers to bear the industry burden of increasing lamb survival from an animal welfare perspective. While this was certainly a minority view, it does raise the issue of market failure in terms of the level of animal welfare (ewe and lamb survival) acceptable to consumers and society more broadly, and the collective level of optimal ewe and lamb survival achieved by individual producers primarily based on maximisation of overall farm profits within limited resource availability.

Finding 7: *The level of lamb survival considered to be acceptable by society and consumers is likely to be higher than the collective level of lamb survival achieved on individual farms aiming to maximise farm profit within limited resource boundaries, thus representing a potential market failure which may require additional government and industry funding to address.*

6.0 Industry Investment in Sheep Reproduction RD&E

6.1 Actual Compared to Recommended Expenditure

Table 3 presents industry investment in sheep reproduction RD&E relative to the investment recommended in the SRRIP. Actual investments were included in the period of analysis at a project level if the project contract was signed between 1st July 2012 and 30th June 2017 to align with the national plan investment period. The actual investment amounts in Table 3 include funding provided by both MLA and AWI, in addition to any in-kind and/or cash funding provided by delivery partners. The amounts also include some expenditure post June 30th 2017 where the project was funded into subsequent financial years according to the initial project contract. The investment does not include sheep reproduction research projects funded by other organisations which did not include at least a portion of funding from MLA and/or AWI, as project investment data where RDCs were not involved was unavailable for this review.

Table 3: Industry investment in sheep reproduction RD&E between 2012/13 and 2016/17 relative to that recommended in the National Sheep Reproduction Plan (2012-2017) (Nominal $)

Investment in Sheep Reproduction	Conception and early embryo mortality	Ewe and lamb survival	Early reproductive success and weaner performance	Genetics and biological mechanisms	Total
Strategic Research					
Plan	$100,000	$1,400,000	$1,000,000	$2,500,000	$5,000,000
Actual	$199,396	$652,418	$0	$3,031,753	$3,883,567
Difference	+99%	-53%	-100%	+21%	-22%
Applied Research					
Plan	$800,000	$4,700,000	$2,200,000	$900,000	$8,600,000
Actual	$2,339,733	$3,605,736	$87,269	$3,227,682	$9,260,420
Difference	+192%	-23%	-96%	+259%	+8%
Development & Extension					
Plan	$400,000	$8,100,000	$1,700,000	$900,000	$11,100,000
Actual	$1,249,708	$5,002,815	$727,424	$586,045	$7,565,991
Difference	+212%	-38%	-57%	-35%	-32%
Total					
Plan	$1,300,000	$14,200,000	$4,900,000	$4,300,000	$24,700,000
Actual	$3,788,837	$9,260,969	$814,693	$6,845,480	$20,709,978
Difference	+191%	-35%	-83%	+59%	-16%

Some projects were categorised as generating outcomes that related to more than one pillar, in which case the funding for those projects was allocated across the relevant pillars based on estimated proportional delivery relating to each pillar. Categorisation of projects as either strategic or applied research was based on whether or not there was an adoptable outcome from the research that could be applied to address an on-farm issue as opposed to just an increase in knowledge gained. If there was an adoptable outcome, the project was categorised as applied. Project investments categorised as 'Development & Extension' included Producer Demonstration Site projects (PDS) and funding associated with development, management and delivery of extension programs.

Some project investments, particularly those involved in the 'Genetics and biological mechanisms' investment pillar, in addition to involving research into sheep reproduction, also involved research into other areas, for example carcase and wool traits. In such cases an estimate of the proportion of

investment relating to sheep reproduction was made in consultation with the relevant funding and delivery organisations.

Table 3 reveals that total investment in sheep reproduction RD&E has been 16% less than that recommended in the SRRIP, with investment in development and extension being the most underfunded area relative to the investment recommended. A discussion of why actual investment in sheep reproduction RD&E has differed from that recommended in the SRRIP is provided in Section 6.2, however it was essentially due to the SRRIP not being utilised by industry as the primary decision-making framework for sheep reproduction RD&E investment over the planning period.

Finding 8: *Total industry investment in sheep reproduction RD&E between 2012/13 and 2016/17 has been 16% less than that recommended in the SRRIP (2012-2017).*

Finding 9: *The value of total industry investment in development and extension activities between 2012/13 and 2016/17 has been around two-thirds of that recommended in the SRRIP (2012-2017).*

Investment in the 'Conception and early embryo mortality' and 'Genetics and biological mechanisms' pillars was higher than that recommended in the SRRIP, while investment in the 'Ewe and lamb survival' and 'Early reproductive success and weaner performance' pillars was lower than that recommended.

Table 4 presents estimated benefit to cost ratios (B:C ratios) by investment pillar for sheep reproduction project investments made during the SRRIP delivery period with an adoption outcome and adoption related on farm productivity impacts.

Table 4: Estimated B:C ratios for investment in each SRRIP pillar

Pillar	Conception & early embryo mortality	Ewe & lamb survival	Early reproductive success and weaner performance	Genetics & biological mechanisms
Investment B:C ratio*	5.1 (1.3 with removal of RAMping Up Repro)	7.1	4.1	1.8

* Only includes project investments in Category 1 with an adoption outcome and adoption related productivity impacts.

Utilising these B:C ratios, had the actual investment amount in the projects included in the impact assessment been apportioned between pillars according to the recommendations in the SRRIP, rather than what actually occurred, and assuming the same B:C ratio by pillar was achieved for reallocated funds, it is estimated that an additional $6.62 million in net present value terms would have been generated from that investment.

To provide a more representative estimate of the benefits foregone by not following the recommended proportional investment by pillar in the SRRIP, one outlier project (RAMping Up Repro) which skewed the B:C ratio considerably for the 'Conception and early embryo mortality pillar' was removed from the analysis as a comparison. Investment in the RAMping Up Repro project represented only 4% of total investment in this pillar for the projects assessed, however benefits from this project represented approximately 75% of total pillar benefits. Removal of the RAMping Up Repro investment from the analysis decreased the B:C ratio for the 'Conception and early mortality' investment pillar by around three-quarters (Table 4). With removal of this outlier project, the estimated additional net present value which could have been generated by following the proportion investment by pillar recommended in the SRRIP, rather than the actual investment that occurred, was $12.68 million.

Finding 10: *Had investment in the projects included in the impact assessment for this review been apportioned between pillars according to the recommendations in the SRRIP, rather than what actually occurred, it is estimated that an additional $6.62 million in net present value terms would have been generated from that investment. With removal of one outlier project from the analysis to provide a more representative assessment, the estimated additional net present value foregone increased to $12.68 million.*

Table 5 presents all industry investment in sheep reproduction RD&E since 1st July 2012 post commencement of the SRRIP. Thus, in addition to project contracts signed by 30th June 2017 (Table 3), it also includes project investments in sheep reproduction in subsequent financial years up until December 2019.

Table 5: Industry investment in sheep reproduction RD&E since 1st July 2012 to December 2019 (Nominal $)

Investment in Sheep Reproduction	Conception and early embryo mortality	Ewe and lamb survival	Early reproductive success and weaner performance	Genetics and biological mechanisms	Total
Strategic Research					
Plan	$100,000	$1,400,000	$1,000,000	$2,500,000	$5,000,000
Actual	$199,396	$829,042	$0	$3,163,367	$4,191,805
Difference	+99%	-41%	-100%	+27%	-16%
Applied Research					
Plan	$800,000	$4,700,000	$2,200,000	$900,000	$8,600,000
Actual	$5,228,560	$14,774,592	$2,373,928	$6,718,340	$29,095,418
Difference	+554%	+214%	+8%	+646%	+238%
Development & Extension					
Plan	$400,000	$8,100,000	$1,700,000	$900,000	$11,100,000
Actual	$1,612,181	$8,745,117	$997,565	$734,758	$12,089,622
Difference	+303%	+8%	-41%	-18%	+9%
Total					
Plan	$1,300,000	$14,200,000	$4,900,000	$4,300,000	$24,700,000
Actual	$7,040,137	$24,348,751	$3,371,493	$10,616,465	$45,376,845
Difference	+442%	+71%	-31%	+147%	+84%

The data in Table 5 indicates that there that been an additional $15.1 million invested in 'Ewe and lamb survival', and a further $3.8 million in 'Genetics and Biological Mechanisms', $3.3 million in 'Conception and early embryo mortality', and $2.6 million in 'Early reproductive success and weaner performance' since mid-2017.

Finding 11: *Total estimated industry investment since July 2012 in the 'Early reproductive success and weaner performance' pillar is around 70% of what was recommended in the SRRIP (2012-2017). Investment in all other pillars has exceeded targets identified in the plan.*

Only around $4.5 million of the additional $24.7 million of funding since mid-2017 has been invested in development and extension activities, and around $300,000 in strategic research, with the vast majority allocated to applied research. The overall outcome is that investment in strategic research since mid-2012 has remained less than that recommended in the national plan.

Finding 12: *Total industry investment since mid-2012 in strategic research has remained less than that recommended in the SRRIP (2012-2017).*

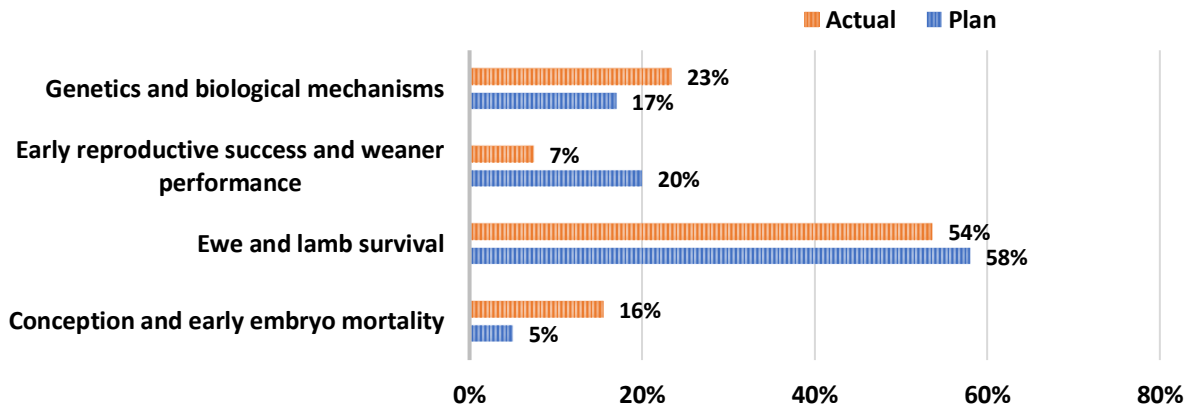


Figure 11: Proportion of funding invested by SRRIP Pillar relative to planned investment (2012-13 to 2019)

Despite an increase in investment in applied research into 'Early reproductive success and weaner performance', this pillar of investment has remained underfunded (by around 13%) relative to the proportion of total investment recommended in the SRRIP, while the 'Conception and early embryo mortality' pillar has been relatively over-funded (Figure 11).

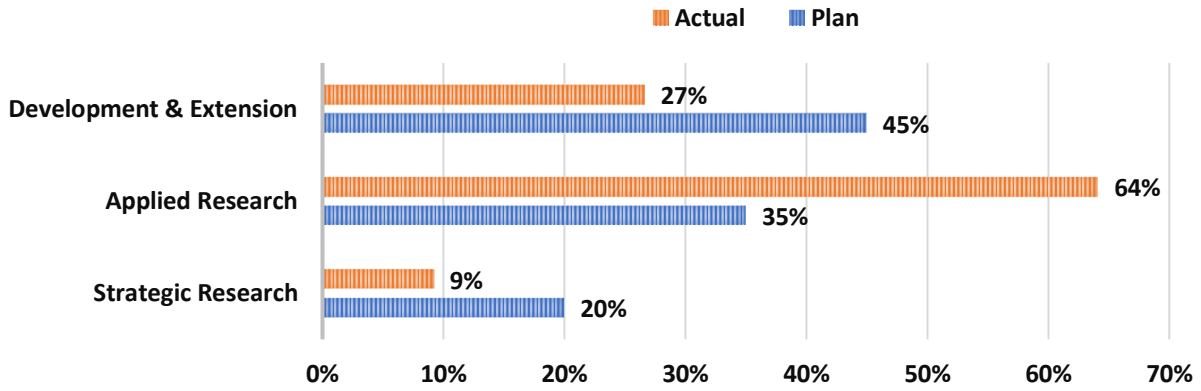


Figure 12: Proportion of funding invested in RD&E areas relative to planned investment (2012-13 to 2019)

Figure 12 reveals that relative to the proportion of investment recommended for RD&E areas in the SRRIP, the proportion of actual expenditure has been 83% higher on applied research, 40% lower on development and extension, and 55% lower on strategic research.

Finding 13: *Relative to what was recommended in the SRRIP, the proportion of total expenditure on sheep reproduction has been 83% higher on applied research, 40% lower on development and extension, and 55% lower on strategic research.*

Figure 13 presents the proportion of total industry expenditure on sheep reproduction RD&E since 1st July 2012 by funding source.

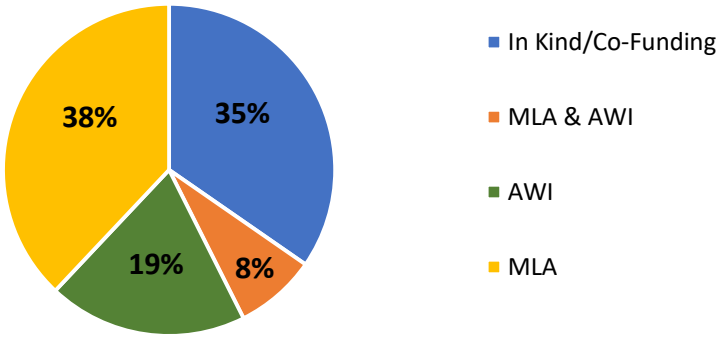


Figure 13: Percentage of total expenditure on sheep reproduction RD&E since 1st June 2012 by funding source

While cash contributions are accurately recorded on project contracts, valuation of in-kind contributions is less robust. There is variation between organisations as to what is valued as part of in-kind support. Staff time is consistently accounted for, however valuation of other inputs, such as infrastructure and equipment, is more variable. It also appears that there are some cases where in-kind staff contributions are over-valued in that the same individual is valued at more than one full time equivalent (FTE) across multiple projects during the same time period.

Finding 14: *In-kind and cash contributions from delivery organisations account for 35% of total investment in sheep reproduction RD&E since mid-2012. While cash contributions are accurately recorded on project contracts, valuation of in-kind contributions is less robust.*

Recommendation 6: *MLA and AWI to work together to develop a consistent process for classifying, valuing and reporting in-kind contributions from delivery partners. This framework should be provided to all delivery partners where in-kind contributions are involved to increase the accuracy of these contributions. It is also recommended that MLA and AWI consider utilising a shared database of individual delivery personnel where in-kind FTEs are recorded against individuals to ensure that in-kind FTE contributions are not over-valued by double counting time.*

Figure 14 reveals that investment in the 'Ewe and lamb survival' pillar leveraged the greatest proportion of in-kind/cash investment from delivery partners and co-funding of projects.

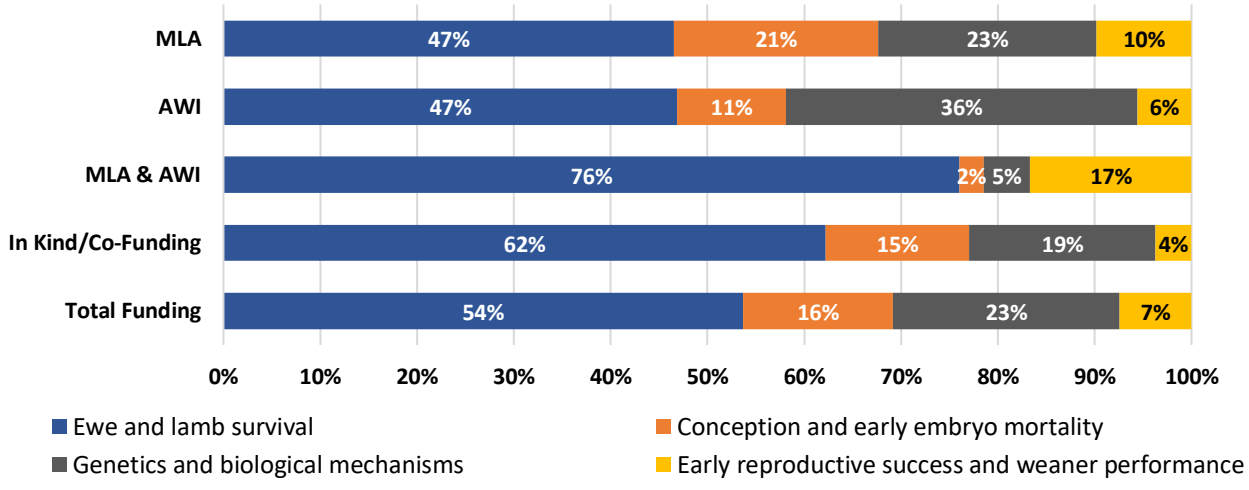


Figure 14: Proportion of funding by source for each investment pillar (July 2012 to December 2019)

Almost half of all funding from both MLA and AWI has been in 'Ewe and lamb survival', while over a third of all AWI funding was in the 'Genetics and biological mechanisms' pillar, compared to around a quarter of all MLA investment in this area. The vast majority of co-investment between MLA and AWI has been in 'Ewe and lamb survival' (76%), followed by investment in the 'Early reproductive success and weaner performance' pillar (17%).

In terms of the type of RD&E being funded, Figure 15 reveals that relative to MLA investments, AWI expenditure has related more to strategic research and development and extension, with relatively less on applied research.

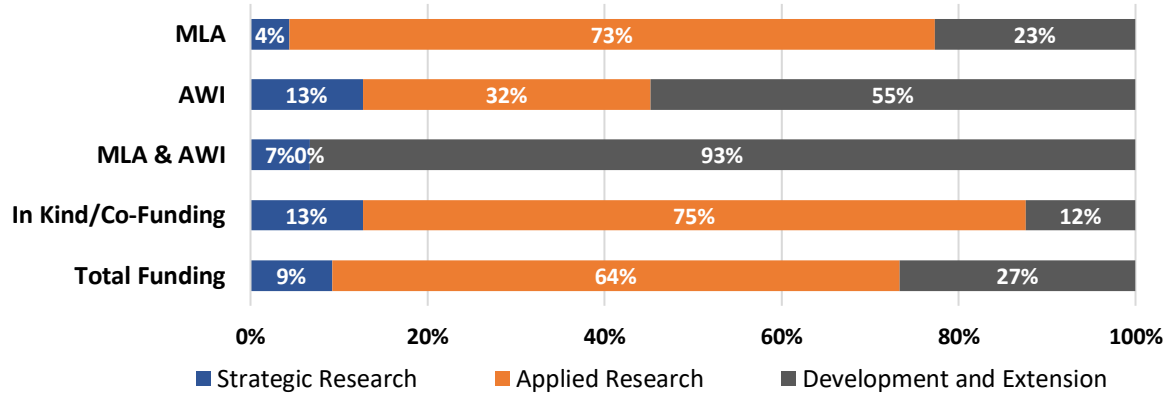


Figure 15: Proportion of funding by source for RD&E areas of investment (July 2012 to December 2019)

MLA and AWI joint investments have predominantly related to delivery of extension programs, including It's Ewe Time, Bredwell Fedwell and Making More from Sheep, with only a small amount of co-investment in strategic research and none in applied research projects. In contrast, the majority of in-kind/cash funding from delivery partners has involved applied research, with only a small proportion for strategic research and development and extension.

6.2 Utilisation of the SRRIP to Guide Industry Investment Decisions

The stakeholder engagement process for this review revealed broad support across industry sectors of the need for a national sheep reproduction plan to define what 'success' looks like, and to provide a framework for investment decision making in key priority areas required to achieve target outcomes. Stakeholder perceived value in having a national sheep reproduction RD&E investment plan included the following:

- Its development creates an opportunity for input from a range of stakeholders into the future direction required to achieve agreed outcomes, thereby creating a shared sense of collective responsibility for achievement of objectives;
- It draws attention to the issue of sheep reproduction;
- It provides a focal point for open discussion of the key issues that require an industry wide focus to address;
- It encourages collaboration by providing an agreed direction for action; and
- It provides a framework for decision making at the project investment level.

Finding 15: *The stakeholder engagement process indicates broad industry support for a National Sheep Reproduction RD&E Investment Plan.*

While these potential benefits of a national plan were identified, it was acknowledged by many stakeholders that not all of these benefits have been realised for the previous plan. The following general comments were made:

- Industry investment against the plan was a focus for a short period of time, however after the first year or two the plan had little to no relevance in decision making at the project investment level.
- An implementation plan was developed to support delivery of the SRRIP, but the plan was not actioned, and nor was there a process of regular monitoring and evaluation of industry investment relative to planned targets.
- A standard process for assessing the likely economic impact of investment in alternative sheep reproduction project options was not utilised by the RDCs.
- The plan seemed to have lost its value as key people involved moved on to other things, and the new people did not have the same, or any, level of historical buy-in to the plan, thus reducing the focus on its utilisation as part of the investment decision making process.

Finding 16: *The stakeholder engagement process indicates a general consensus that the potential value of the National Sheep Reproduction RD&E Investment Plan (2012-2017) has not been realised due to a lack of broad industry commitment and leadership around implementation of the plan.*

While the concept of a national investment plan for sheep reproduction is broadly supported by industry, there is a need for such a plan to be utilised in a more structured way to guide investment decision making in agreed priority areas. Various stakeholders commented that while they were supportive of development of a new national sheep reproduction plan, that it should be developed with broader industry consultation across all sectors (research, extension, producers, supply chain), be developed by an independent person/people, and be accompanied by an operational plan for delivery.

It was also reported by stakeholders that while the SRRIP was originally developed under the guidance of an industry steering committee, the committee had little influence over subsequent implementation of the plan. Personnel changes reportedly left the plan without a dedicated focus for ongoing implementation to ensure that project funding decisions aligned with the priorities of the SRRIP, and to monitor progress in consultation with RDC boards and producer organisations. Over time, changes in the way that projects have been commissioned and prioritised within MLA and AWI has occurred, including establishment of the Southern Australian Livestock Research Council (SALRC) and the Western Australian Livestock Research Council (WALRC), without due reference given to the role of the SRRIP.

Overall, there was a lack of resourcing to support ongoing governance planning and accountability to ensure that the SRRIP was effectively implemented and monitored to achieve its objectives. It was beyond the scope of this review to assess the processes and criteria that have actually been utilised in place of the SRRIP to prioritise industry funding for project investments in the area of sheep reproduction.

Finding 17: *The SRRIP has not been effectively utilised over the term of its life to guide project investment decisions for sheep reproduction RD&E. Overall, there was a lack of resourcing to support ongoing governance planning and accountability to ensure that the SRRIP was effectively implemented and monitored to achieve its objectives.*

Recommendation 7: *A new National Sheep Reproduction RD&E Investment Plan be developed for commencement in 2020/21. The next version of the plan should:*

- *Involve broad industry consultation across all relevant sectors and organisations;*
- *Establish a clear purpose for the plan including industry outcomes that reflect all stakeholder needs;*
- *Establish national objectives and KPI targets that align with the objectives of other relevant industry strategic plans;*
- *Be developed/co-ordinated by an independent person/persons (e.g. RDCs/external provider not linked to delivery);*
- *Involve utilisation of an agreed standard process for evaluating the potential economic benefits from alternative project investments;*
- *Be accompanied by an operational plan for delivery and a monitoring and evaluation framework for assessing delivery progress against KPIs and to modify the direction of the plan if deemed necessary;*
- *Be implemented under the direction of an industry representative steering committee of organisations and sectors committed to achieving the intended outcomes of the plan; and*
- *Establish appropriate governance and accountability structures and processes for implementation, monitoring and evaluation.*

It is understood that initially MLA had committed funding to implementation of the SRRIP, but that AWI had not. Over the subsequent years, this commitment diminished as other strategic plans and internal processes for prioritising project investments in sheep reproduction took precedence over the SRRIP. For a new SRRIP to be successfully implemented it would therefore require formal commitment from all industry partners for the duration of the planning period.

Finding 18: *For a new SRRIP to be successfully implemented it would require formal commitment from all industry partners for the duration of the planning period.*

Recommendation 8: *Establish formal commitment to implementation of a new SRRIP through a binding partnership agreement with all relevant partners to commit funds and resources to implementation of the plan for its duration.*

6.3 MLA and AWI Investment in Sheep Reproduction RD&E

A consistent message reported by stakeholders during the consultation process for this review was that sheep reproduction is a critical issue for the sheep industry, with particular reference to the issue of lamb survival, and that as such, it is under invested in by the RDCs. Irrespective of the target levels of investment identified in the SRRIP, there was particular concern expressed by many that extension and adoption of sheep reproduction R&D is significantly under-funded relative to what is perceived to be required for the level of practice change needed to achieve sustained improvement in lamb survival.

Finding 19: *According to stakeholder feedback, relative to the perceived importance of the issue of lamb survival to the sheep industry, the level of funding allocated by the RDCs to sheep reproduction RD&E, particularly to development and extension activities, is inadequate to achieve the desired industry outcomes for lamb survival.*

Table 6 presents the proportion of MLA RD&E expenditure on sheep productivity and sheep reproduction by financial year.

Table 6: MLA investment in RD&E by financial year (nominal $)

Investment Period	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
Sheep levies received as % all levies	33%	32%	32%	33%	35%	37%	35%
RD&E expenditure on increasing productivity and profit ($ mill)	$36.5	$39.1	$36.2	$29.2	$37.6	$73.6	$65.5
Sheep reproduction RD&E expenditure as a % of total expenditure on increasing productivity and profit	4.1% (estimate)	3.8% (estimate)	4.1% (estimate)	5.1% (estimate)	4.0% (estimate)	2.0% (estimate)	n/a

Source: MLA

Table 7 presents the proportion of AWI RD&E expenditure on sheep productivity and sheep reproduction by financial year.

Table 7: AWI investment in RD&E by financial year (nominal $)

Investment Period	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19
RD&E expenditure on increasing sheep productivity and profit ($ mill)	$16.3	$18.7	$13.6	$11.0	$10.8	$14.0	$18.5
Sheep reproduction RD&E expenditure as a % of total expenditure on increasing sheep productivity and profit	4.0%	4.6%	11.8%	15.1%	18.7%	13.5%	5.2%

Source: AWI

Finding 20: *MLA expenditure on sheep reproduction RD&E represents around 4% of the available funding for RD&E to increase farm profitability and productivity. AWI expenditure on sheep reproduction has varied between years at an average of around 10% of total RD&E expenditure over the past 7 years.*

Recommendation 9: *MLA and AWI to review their level of relative investment in sheep reproduction RD&E in light of the perceived misalignment between the importance of the issue of lamb survival, particularly from an animal welfare perspective, relative to the proportion of RD&E funds invested in addressing the issue.*

It is also suggested by the authors that the contribution of outcomes from some areas of sheep reproduction RD&E toward MLA and AWI organisational objectives in animal welfare and environmental sustainability may be undervalued. It is therefore suggested that these issues are possibly being under-funded relative to the range of benefits they generate to industry across multiple strategic priority areas.

For example, in the 2018/19 financial year, MLA expended $17.7 million in the area of 'Stewardship of environmental resources' and $20.4 million in the area of 'Continuous improvement of the animals in our care' under the Strategic Pillar: Consumer and Community Support. Of these amounts, only 1.4% of the $17.7 environmental amount and 5.8% of the $20.4 million animal health and welfare amount were spent on R&D relating to sheep production systems. Thus, there may be scope to justify increased funding for RD&E relating to increasing ewe and lamb survival on animal welfare grounds and on both increasing ewe and lamb survival and reproductive efficiency of ewe lambs on the grounds of demonstrated environmental benefits in reducing the carbon footprint per unit of product output.

Recommendation 10: *MLA and AWI to explore the scope for increasing funding allocated to key areas of sheep reproduction RD&E, such as increasing ewe and lamb survival and increasing the reproductive efficiency of ewe lambs, on the grounds that outcomes from these areas of RD&E also contribute to organisational objectives for environmental and animal health and welfare outcomes.*

7.0 Sheep Reproduction RD&E Achievements

7.1 Research Achievements

Table 8 provides a summary of the sheep reproduction R&D achievements for each product category.

Table 8: Key achievements for sheep reproduction research product categories

Research Product Category	Key Achievements	Adoption Outputs Impacting on Sheep Reproduction Outcomes
Conception/Early embryo mortality	• Increased recognition of the role of heat stress in reproductive performance. • Increased producer and service provider /consultant knowledge around identification and management of oestrogenic clovers. • Increased understanding of the role of nutrition in influencing the sex ratio of lambs. • Increased understanding of the role of short-term flushing on ewe conception rates.	• Guidelines for producers/service providers in identification and management of oestrogenic clovers.
Maiden ewe management	• Demonstrated that there is higher than average lamb wastage in weaner/maiden ewes compared to mature ewes. • Increased knowledge of the variability in ewe lamb conception, scanning and lamb survival rates between breeds. • Increased understanding of the barriers to adoption of ewe lamb mating by producers. • Increased understanding of impact on lamb survival of prior exposure of pregnant maiden ewes to lambing mature ewes. • Increased understanding of the influence of maiden ewe age, pre-joining weight, condition score and progesterone levels on subsequent lambing outcomes. • Increased knowledge around the profitability of ewe lamb mating.	• None

Research Product Category	Key Achievements	Adoption Outputs Impacting on Sheep Reproduction Outcomes
Ewe nutrition (CS)	• Demonstrated condition score targets for Maternal and Dorper ewes that are different from the recommendations for Merino ewes. • Demonstrated that liveweight (for Dorpers) and condition score profiles (for non-Merinos) can predict the production of ewes and their progeny. • Demonstrated the impact of losing condition during pregnancy on non-Merino ewe mortality and the difference in feed intake at same Feed on Offer (FOO) compared to Merino ewes. • For Dorpers, demonstrated that a liveweight of 60 kg CS 3 at joining with ewes gaining weight pre and early joining gives optimum conception. • Demonstrated significant changes in lamb growth and development dependent on periconceptional nutrition and, for the first time, links these changes with significant changes in behaviour of the neonate (the impact of these effects on lamb survival and potential reproductive capacity of female offspring remains to be determined). • Increased understanding of focus feeding to improve fecundity and lamb survival in Merino ewes.	• Draft tech note for Dorper producers with guidelines for monitoring ewe liveweight rather than CS and feeding to maintain weight during lactation to increase lamb weaning weights. • Non-Merino feed intake tables are under development for addition to LTEM manual. • Updated versions of two producer guidelines: "A producers' guide to production feeding for lamb growth" and "National procedures and guidelines for intensive sheep and lamb feeding systems".
Ewe nutrition (Diet/supplements)	• Increased understanding of impact of mineral deficiencies on pregnant ewes and lamb survival. • Increased understanding of the role of vitamins and various supplements in ewe health and lamb survival. • Increased understanding of how high-salt feeding during ewe pregnancy affects the physiology and performance of the offspring.	• Recommendations for feeding ewes calcium and magnesium fact sheet.
Lamb survival (Management)	• Improved recommendations for mob size/lambing density. • Increased knowledge around how shorter shearing interval impacts on lamb survival. • Demonstrated technique to age fetuses for accurate discrimination of early from late lambing ewes in commercial flocks.	• New recommendations for mob size to be incorporated into relevant extension programs.
Lamb survival (Biological)	• Increased knowledge of if and how a range of biological processes impact on lamb survival which include: - Quantity and quality of colostrum production - Role of leptin in bone development and lung structure in lamb foetuses - Role of dexamethasone on neurodevelopmental outcomes for preterm lambs and on reducing preterm brain injury following chorioamnionitis - Role of ewe nutrition on lamb B-cell secretion and hypothalamic control This research was undertaken by various universities and NSW DPI without RDC funding.	• None
Ewe survival	• Nothing to date as all projects in this product category are still in progress.	• None

Research Product Category	Key Achievements	Adoption Outputs Impacting on Sheep Reproduction Outcomes
Applications for sensor technology	• Demonstration of sensors for maternal pedigree matching on commercial farms. • Progress towards development and demonstration of sensor technology (Smart Tags) to assist with the reproductive management of naturally mated sheep. • Progress towards development of a protocol using sensor technology for implementation of variable time AI programs without PMSG.	• None
Improved ASBVs	• Improved repro ASBV & RBV accuracy (inclusion of MLP lifetime data in MERINOSELECT/updated accuracy algorithm/improved analysis models/additional data via the mating module/additional management grouping for reproduction analysis). • New maternal yearling and adult reproduction RBVs: conception (con), litter size (ls), ewe rearing ability (era). • Dohne Merino reproduction trait analysis. • Use of pregnancy scanning data to inform reproduction analyses. • Improved lambing ease and gestation length breeding values. • Additional correlated traits (joining weight and CS and maternal behaviour score).	• New maternal RBVs available • Dohne repro ASBVs available (NLW/NLB) • Increased repro ASBV accuracy
Selection strategies and tools	• Confirmation of twice dry culling as the most effective ewe selection strategy for reproductive performance. • Demonstrated that Merino ewes and lambs take hours more to learn to recognise each other relative to other breeds, indicating a genotype difference for the bonding/memory process.	• None
Artificial breeding	• Commercialisation of ram semen sexing (Sexing Technologies P/L). • Increased knowledge on how to improve success of cervical AI with frozen semen. • Progress toward development of protocols for increased levels of synchrony of oestrus.	• Availability of sexed ram semen technology for producers.

The information presented in Table 8 indicates that there has been a considerable amount of sheep reproduction research which has generated new knowledge to address information gaps, but much of which has not translated to adoptable products to increase reproduction efficiency on farms.

Finding 21: *Since the inception of the SRRIP, there has been a considerable amount of sheep reproduction research and development which has generated new knowledge to address information gaps, but much of which has not translated to adoptable products to increase reproduction efficiency on farms.*

7.2 Development, Extension and Adoption Achievements

Table 9 provides a summary of the achievements for each adoption product.

Table 9: Key achievements for sheep reproduction adoption products

Adoption Product	Key Achievements
Producer Demonstration Sites (PDS) - **Temporary fencing to reduce mob size**	**Core producers:** 3 **Observer producers:** 23 **Sheep:** 75,000 **Adoption:** 100% of core producers/40% of observers plus 5% flow on local adoption impacting 13,000 ewes
- **Chaff carts as sheep management tools**	**Core producers:** 10 **Observer producers:** 120 **Total ewes:** 910,000 **Adoption:** 70% of core producers/60% of observers plus 5% flow on local adoption impacting 430,000 ewes
- **Shelter to increase lamb survival**	**Core producers:** 9 **Observer producers:** 50 **Total ewes**: 118,000 **Adoption:** 70% of core producers/25% of observers plus 5% flow on local adoption impacting 11,700 ewes
- **Nutritional manipulation of lamb sex ratio**	**Core producers:** 8 **Observer producers:** 20 **Total sheep:** 130,000 **Outcomes:** No impact
- **Reducing the impact of oestrogenic clovers**	**Core producers**: 12 **Observer producers:** 160 **Total ewes:** 430,000 **Adoption:** 17% of core producers/5% of observers plus 5% flow on local adoption impacting 80,400 ewes
- **Measuring behaviour to improve maternal ability**	**Core producers:** 5 **Observer producers:** N/A **Outcomes:** No impact
It's Ewe Time forums	**Workshops delivered:** 23 **Producers attending:** 820 **Total ewes:** 1,131,039 **Adoption**: 656,600 ewes
Lifetime Ewe Management program (2012-2019)	**Producers attending:** 2,927 **Total ewes:** 8,075,594 **Adoption:** 5,306,300 ewes
Bredwell Fedwell program (Phases 2,3 and 4)	**Programs delivered:** 124 **Producers attending:** 1,694 **Total ewes:** 5,127,738 **Adoption:** 1,579,600 ewes
Profitable Grazing Systems (Lamb Survival)	**Programs delivered:** 13 **Producers attending:** 96 **Total ewes:** 318,720 **Adoption:** 177,000

Adoption Product	Key Achievements
Merinos to Market/Realising Performance Potential	**M2M (Merinos to Market) workshops:** 5 pilots **Realising Performance Potential (RPP) workshops:** 11 **Producers attending:** 160 **Total ewes:** 447,790 **Adoption:** 128,400 ewes
RAMping Up Repro	**Programs delivered:** 35 **Producers attending:** 732 **Total ewes:** 2,394,372 **Adoption:** 1,051,100 ewes
Making More from Sheep – Reproduction only	**Reproduction workshops delivered:** N/A **Producers attending:** N/A **Total ewes:** N/A **Adoption:** 900,000 ewes

Table 10 provides a summary of available demographics of producers participating in each key sheep reproduction extension program.

Table 10: Distribution of producer participants by enterprise size for key sheep reproduction extension programs

No. Sheep per Business	Population (ABARES 2017/18)	Bredwell Fedwell	It's Ewe Time	PGS (LLS)	Lifetime Ewe Management
Less than 2,500	68%	53%	71%	55%	29%
2,500 - 5,000	20%	30%	20%	26%	39%
5,001 – 10,000	10%	14%	7%	16%	22%
10,000+	3%	3%	2%	4%	10%

It's Ewe Time is the only program which collected any information on age of producer participants (2017 and 2018 only). Figure 16 presents this data in comparison to the national distribution of farmer age.

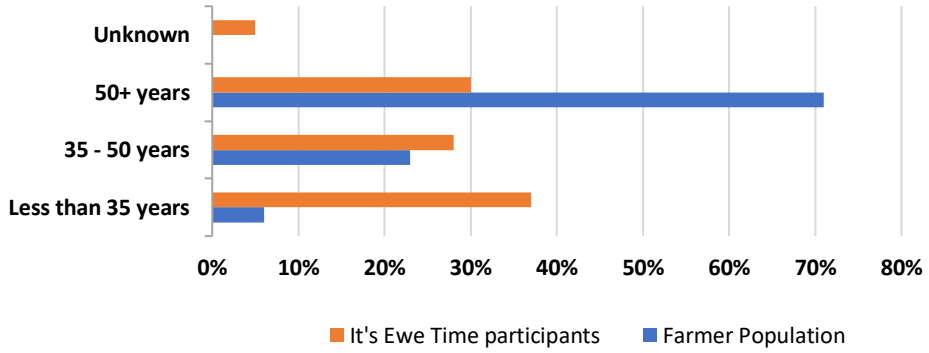


Figure 16: National age distribution for farmers (ABS census 2016) compared to It's Ewe Time participants (2017 & 2018)

Of all of the extension products delivered since inception of the SRRIP, the LTEM program has had the most influence on sheep reproduction efficiency, impacting the management of around 6 million ewes in the past 6 years. LTEM evaluation data indicates that over time, the impact of the program on delivering producer gains in reproduction and ewe mortality has declined. The average increase in weaning rate post attendance at LTEM over the first 6 years of the program was around 9%, compared to around 5% over the last 6 years of program delivery. Similarly, the average decrease in ewe mortality

for participants in the first 6 years of the program was 1.5%, compared to 0.7% over the last 6 years of the program. This reduction has largely been due to an increase in the level of best management practices already being undertaken by producers before they engage in the LTEM program, thus providing less potential to improve due to participation in the program.

Finding 22: *Of all of the extension products delivered since inception of the SRRIP, the Lifetime Ewe Management program has had the most influence on sheep reproduction, impacting the management of around 6 million ewes in the past 6 years. However, over recent years the impact of the program on delivering producer gains in reproduction and ewe mortality has declined.*

Table 11 presents the difference in producer utilisation of a range of management practices reported in pre-LTEM surveys in the first 6 years of the program, compared to the last 6 years of the program.

Table 11: Changes in LTEM participant pre-program utilisation of a range of management practices over time

Management Practice	Proportion of Producers Utilising Practice Pre-LTEM		
	2008-2013	2014-2019	% Change
CS ewes	4%	19%	+365%
Manage ewes to CS	16%	36%	+124%
Assess FOO	24%	49%	+102%
Assess pasture quality	26%	58%	+120%
Calculate ME balance	1%	5%	+258%
Allocate paddocks on FOO & CS	11%	33%	+196%
Scan - Wet/Dry only	35%	31%	-14%
Scan – Wet/Dry/Litter size	22%	45%	+101%
Manage multiples separately	17%	37%	+120%
Quantify lamb survival	14%	36%	+158%
Quantify ewe mortality	36%	52%	+46%

Source: LTEM participant survey data

The increase in the proportion of participants already utilising a range of best practice management strategies prior to participation in LTEM may be due to knowledge gained over time as key extension messages are more broadly promoted via various other sources and programs (including via other farmers), along with increased motivation to increase lamb marking rates due to higher lamb prices.

The LTEM evaluation data shows that the single most important management practice leading to improved lamb marking rates is the adoption of pregnancy scanning for multiples and differential management of multiple bearing ewes (Thompson, 2019). The producers who were already pregnancy scanning and utilising differential management for multiple bearing ewes prior to participating in LTEM had also already adopted many of the other recommended best management practices, thus the scope for further improvement was generally less among these participants. Thompson (2019) reported that together with flock size (greater improvement among smaller flocks), adoption of pregnancy scanning and differential management of multiple bearing ewes explained 86% of the changes in lamb marking rate due to participation in LTEM.

Despite the potential gains for producers by adoption of scanning and differential management of multiple bearing ewes, this practice is one of the least adopted post LTEM, with an average of 67% of

producers utilising this practice after attending LTEM between 2011 and 2019. It should however, be noted that this rate of adoption has increased to an average of 81% over the past 5 years.

LTEM participant data indicates that adoption of scanning varies geographically due to variation in enterprise mix and scale of operations across regions (Figure 17).

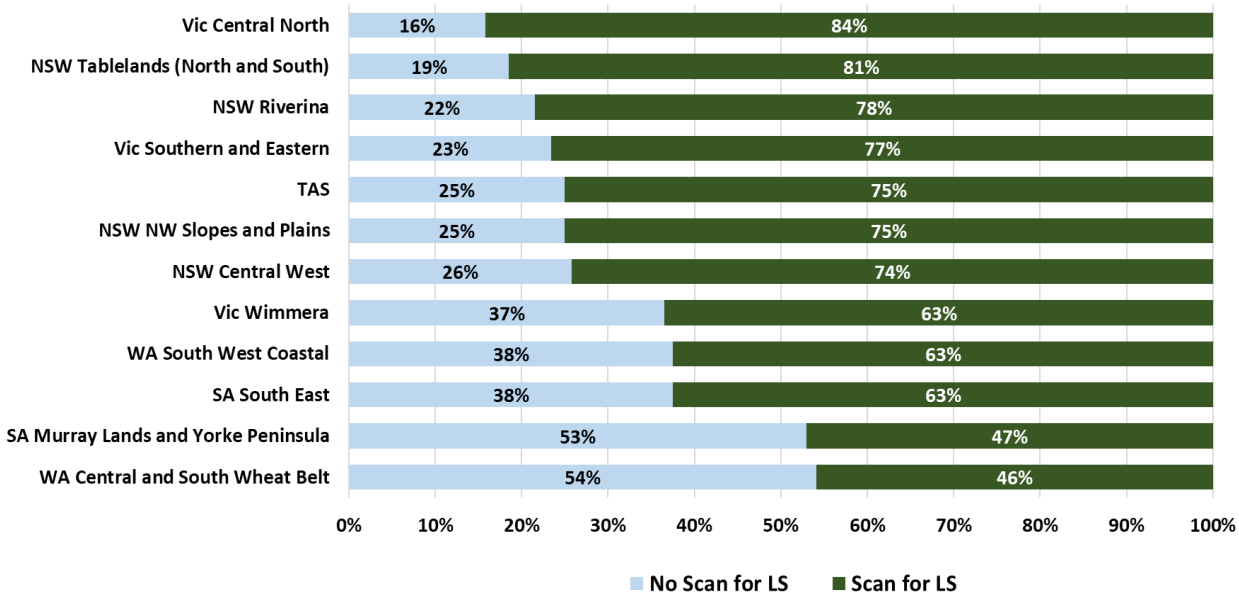


Figure 17: Proportion of LTEM participants in various regions scanning for litter size (LS) (Source: LTEM participant data 2008-2018)

The broader scale cropping areas in Western Australia (WA), South Australia (SA) and Victoria have lower rates of adoption of scanning compared to the more intensive, predominantly sheep producing areas of each state. Table 12 illustrates the larger average farm size, greater proportion of area cropped and lower average stocking rate for those businesses not adopting scanning after attending LTEM compared to those that do adopt.

Table 12: Participant data for those adopting and not adopting scanning post LTEM

Variable	Scanning for multiples post LTEM	Not scanning for multiples post LTEM
% Participants	69%	31%
Av. Farm Size (Ha)	2,444	3,151
% Farm area cropped	23%	28%
No. ewes	3,084	3,047
% Ewes Merino	64%	76%
Stocking Rate (dse/Ha)	9.4	8.2

Source: LTEM participant data 2008-2018

A national survey of 600 sheep producers undertaken during 2015/16 to assess sheep animal husbandry practices reported on reasons provided by producers for not pregnancy scanning and for not managing single and multiple bearing ewes separately (Howard and Beattie, 2016) (Figures 18 and 19).

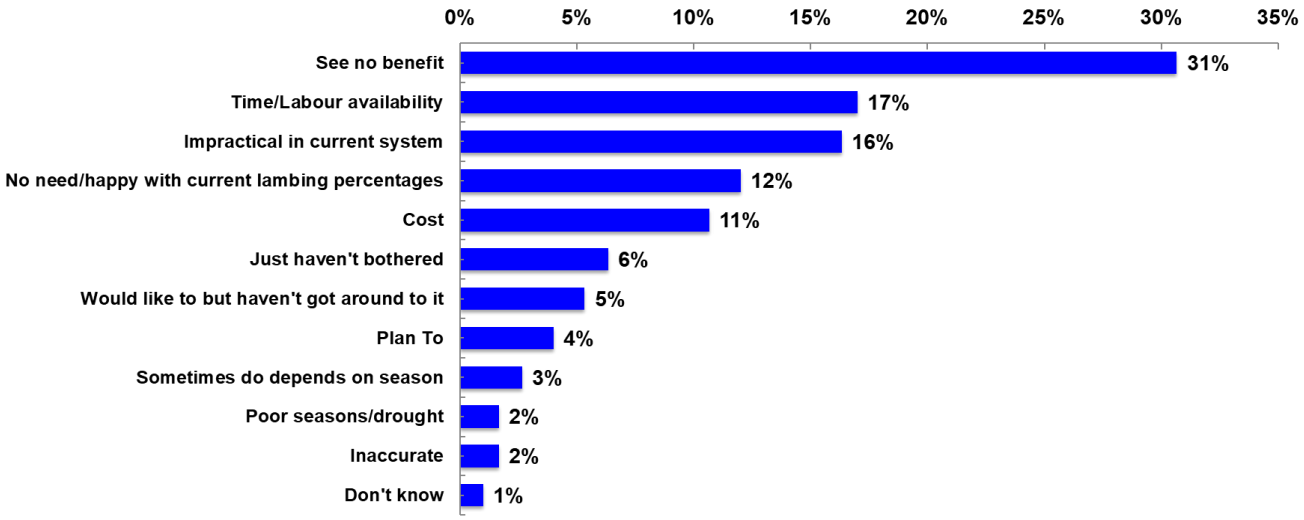


Figure 18: Producer reported reasons for not pregnancy scanning ewes (n=300) (Source: Howard and Beattie, 2016)

The survey found that the most important reason provided for not scanning was that producers saw no benefit in doing so. This finding illustrates the need for extension programs to provide a clear value proposition for individual producers for adoption, of not only scanning, but of all relevant best management practices for increasing sheep reproduction efficiency.

The survey also found that most producers who did scan for multiples also managed single and multiple bearing ewes differentially (94%), however for those that did not, Figure 19 indicates that lack of paddock availability was the major reason reported.

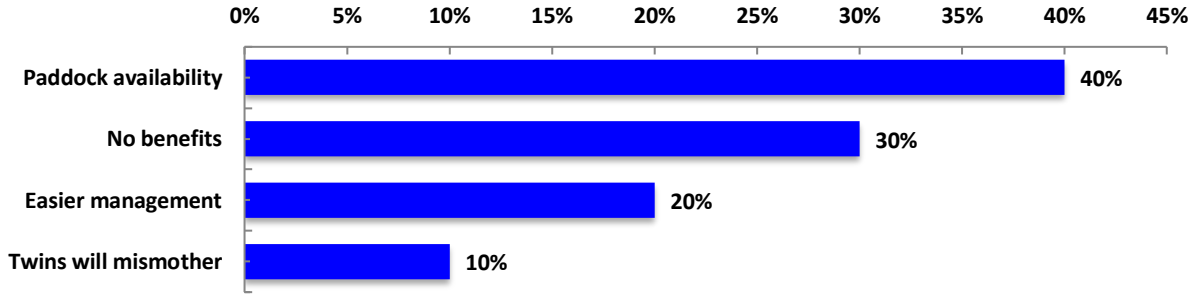


Figure 19: Reasons provided by producers for not managing scanned single and multiple bearing ewes separately (n=12) (Source: Howard and Beattie, 2016)

This data illustrates that a clear understanding of the type of producers who are and are not adopting particular best management practices and why they are or are not adopting will assist to better define on farm 'problems' that need to be solved by R&D and to better target audiences and adoptable products by region for extension programs.

8.0 Achievement of Sheep Reproduction Strategic Objectives

The three most useful datasets available to assess changes in national sheep reproduction rates over time are:

Australian Bureau of Agricultural & Resource Economics & Sciences (ABARES)

- Sample size approx. 850 sheep producers
- Data collection method – random selection, face-to-face interviews with owner/manager
- Business types – greater than $40,000 of estimated value of agricultural operations (EVAO) per business

Australian Bureau of Statistics (ABS)

- Sample size approx. 8,600 sheep producers
- Data collection method – random selection, self-submitted.
- Business types – greater than $40,000 EVAO

MLA and AWI Wool and Sheep Meat Survey

- Sample size approx. 2,000 sheep producers (3 x per year)
- Data collection method - 2.5% self-select via web link, rest random selection. Response: 2% via phone survey, 98% via self-submitted email or mailout survey
- Business types – all

The ABARES dataset is considered by most, including the authors, to be the most accurate of these datasets given that the data is collected on farm, with an opportunity to validate the data with the producer. The producer survey conducted for this review requested data on ewes joined, scanning rates and lambs marked, and this data was provided in a range of different formats and degrees of accuracy (i.e. rounding numbers to the nearest '000), thus illustrating the limitations associated with collecting productivity data from producers via self-submitting processes.

In relation to the sheep reproduction KPIs for the various industry strategic plans identified in Table 1, these three data sets provide figures for lamb marking rate and sheep death rate (ABARES only) for all sheep post weaning. Lamb marking rate is split by Merino lambs and all other lambs by both ABS and the MLA/AWI survey, however ABARES provides a total marking rate for all ewes and a marking rate for lamb slaughter enterprises (more than 200 slaughter lambs sold per year in the previous three-year period). For this impact assessment an estimate of ABARES marking rate for Merino lambs has been calculated as the weighted difference between the total marking rate and the lamb slaughter marking rate based on the proportion of ewes joined in each data set.

Figures 20 to 22 present the change in lamb marking rate for all ewes, Merino x Merino lambs and all other lambs between 2010/11 and 2017/18 for these three datasets.

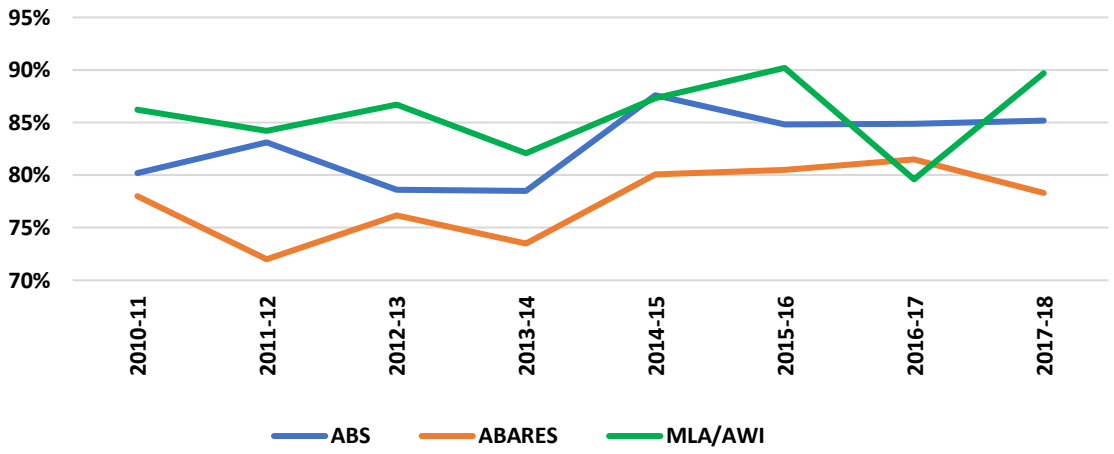


Figure 20: Changes in lamb marking rate by data source for Merino x Merino enterprises

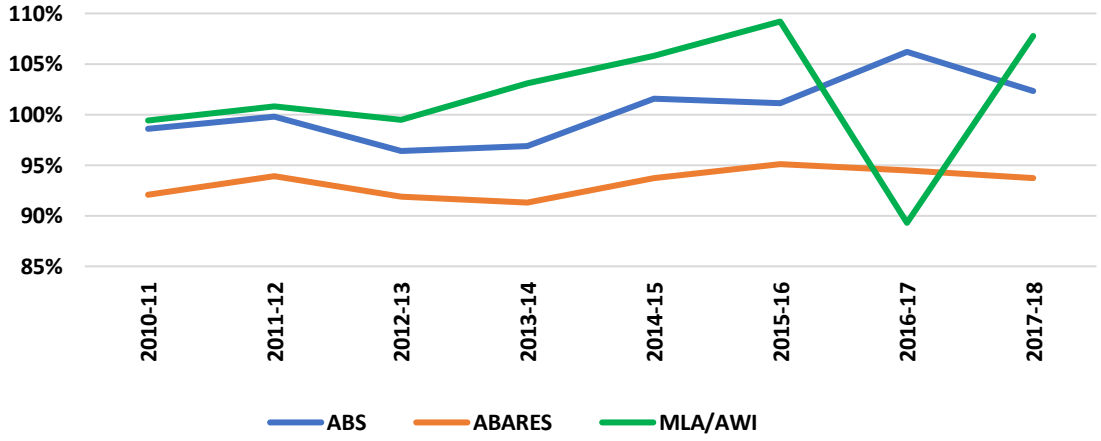


Figure 21: Changes in lamb marking rate by data source for all ewes (incl. Merino) x non-Merino rams

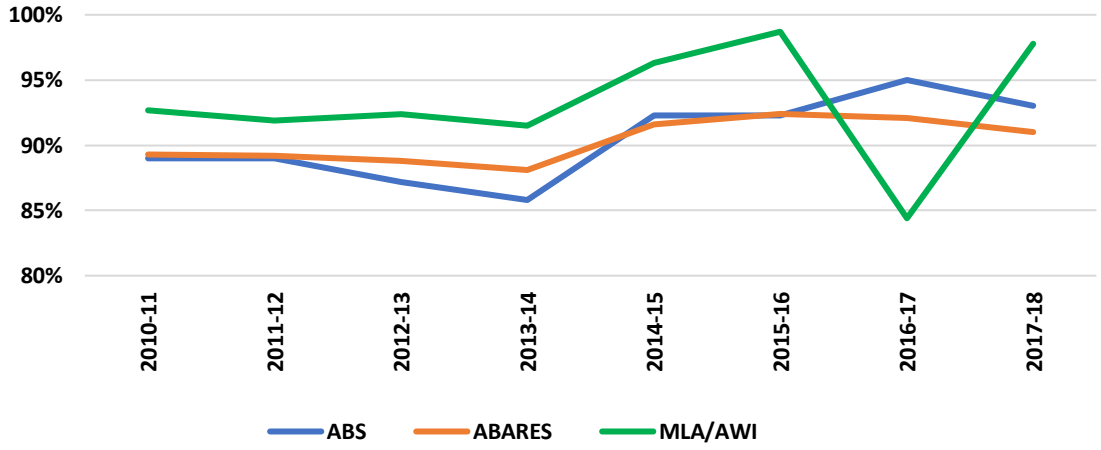


Figure 22: Changes in lamb marking rate by data source for all ewes

The 2016/17 values from the MLA/AWI producer survey represent a considerable divergence from the ABS and ABARES data for the same year. According to the administrator of the MLA/AWI survey (Kynetec), the lower marking rate for 2016/17 was due to a much lower marking rate in the October survey (representing markings July through to October 2016). Kynetec suggest that this was most likely

due to extreme rainfall in various areas of Australia during that period, with significant flooding experienced in central NSW, western Victoria, parts of western QLD and areas around Adelaide. It is suggested by the authors that the MLA/AWI results may have been unduly influenced by a greater proportion of participants located in areas impacted by flooding relative to the proportion in the ABS and ABARES survey population. In any case, given the very large variation in the 2016/17 marking rate reported in the MLA/AWI survey relative to the previous year, and that the ABS and ABARES survey data do not reflect the same trend, the authors have excluded the 2016/17 MLA/AWI survey marking rate data from this analysis.

Table 13 provides the results of a regression analysis on each of the available national datasets for recording reproduction rates over time. The 2017/18 year involved very difficult seasonal conditions for many producers, thus the lamb marking data has also been presented with removal of this year from the analysis as a comparison. Values for 'All ewes' have been adjusted to account for the influence of changes in the relative proportion of Merino x Merino compared to 'All other' joinings over time.

Table 13: Annual national rate of gain in lamb marking percentage since commencement of the SRRIP

Data Source	Breeding System	2012/13 – 2017/18		2012/13 – 2016/17	
		Annual Rate of Gain (% points)	R^2	Annual Rate of Gain (% points)	R^2
ABS	All ewes*	1.5%	71%	2.1%	82%
	Mer x Mer	1.4%	48%	1.9%	53%
	All Other	1.6%	69%	2.4%	89%
ABARES	All ewes*	0.6%	49%	1.1%	73%
	Mer x Mer (estimate)	1.0%	38%	1.8%	68%
	All other (Slaughter lamb category)	0.6%	52%	0.9%	75%
MLA and AWI Survey**	All ewes*	1.4%	68%	2.3%	82%
	Mer x Mer	1.1%	45%	1.6%	37%
	All other	1.7%	73%	3.2%	99%
Average (ABS and ABARES only)	All ewes	1.1%	N/A	1.6%	N/A
	Mer x Mer	1.2%	N/A	1.8%	N/A
	All other	1.1%	N/A	1.6%	N/A

*Adjusted for changes in relative proportion of 'Mer x Mer' vs 'All Other' joinings

* * Excluding 2016/17 year data due to anomaly

Note: R^2 is the proportion of variation in marking rate that is predictable by year. E.g. R^2 of 100% means that we can predict with 100% accuracy what the change in marking rate will be for each year.

The key findings from Table 13 include:

- ABARES data shows a lower average annual rate of gain in marking rate compared to both the ABS and MLA/AWI data sets.
- The R^2 values indicate that there is generally greater variability between years in Merino lamb marking rates relative to that for all other lambs.
- Average annual national rate of gain for total lamb marking percentage is likely to be somewhere between 0.6% and 1.5% over the SRRIP delivery period.
- The average annual national rate of gain in marking rates during the SRRIP delivery period is likely to have been between 1.0% and 1.4% for Merino lambs and between 0.6% and 1.7% for all other lambs.
- Removal of data for the 2017/18 year results in an increase in average annual rate of gain in marking rate across all three data sets.

Finding 23: *The average annual national rate of gain in marking rates during the SRRIP delivery period is likely to have been between 1.0% and 1.4% for Merino lambs and between 0.6% and 1.7% for all other lambs.*

While no national time series data is available on ewe scanning rate, benchmarking data is collected and reported for WA by the Department of Primary Industries and Regional Development (DPIRD) (Figure 23). Producers self-select for participation by entering farm information into an online scanning benchmarking tool on the DPIRD website, therefore the data is not statistically representative of all WA producers. The average number of producers surveyed has increased over time, from 90,109 in 2016 to 142,672 in 2019.

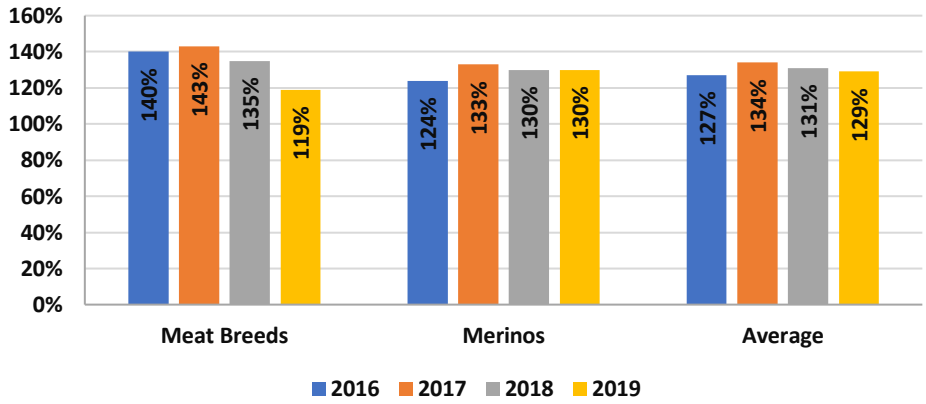


Figure 23: Changes in average and breed scanning percentages for Western Australia (Source: DPIRD Scanning Benchmarking Tool data, M. Curnow pers. comm.)

The results of a regression analysis of the WA producer scanning data is provided in Table 14. The analysis indicates a considerable average annual decrease in meat breed scanning percentage of 7.1%, and a slight average annual increase in scanning percentage for Merinos, though with a much lower R^2 value than for the meat breeds trend. Removing the 2016 data set from the analysis provides for much more accurate trend data, which shows a decrease in scanning percentage over time averaging 2.5% across all breeds.

Table 14: Regression analysis results for WA producer scanning data

Breed	2016 – 2019		2017 – 2019	
	Annual Rate of Gain (% points)	R^2	Annual Rate of Gain (% points)	R^2
Meat breeds	- 7.1%	74%	- 12.0%	96%
Merinos	+ 1.5%	26%	- 1.5%	75%
Average	+ 0.3%	2%	- 2.5%	99%

Figure 24 presents ABARES data for annual sheep death rate post weaning between 2010/11 and 2017/18.

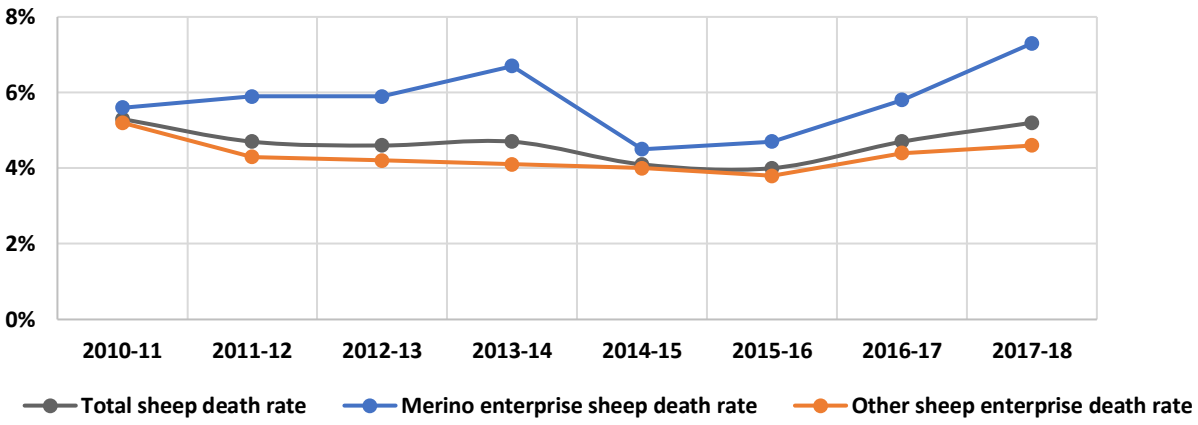


Figure 24: Annual sheep death rate post weaning (ABARES Farm Survey data)

Table 15 provides the results of a regression analysis of sheep death rates over time (all sheep post weaning). There is no national data available to assess changes over time in ewe death rates.

Table 15: Annual rate of change in sheep death rate (all deaths post weaning) since commencement of the SRRIP (ABARES Farm Survey data)

Breeding System	2012/13 - 2017/18		2012/13 - 2016/17	
	Annual Rate of Change (% points)	R^2	Annual Rate of Change (% points)	R^2
All ewes*	+ 0.09%	12%	- 0.03%	5%
Mer x Mer (estimate)	+ 0.13%	5%	- 0.22%	15%
All other (Slaughter lamb category)	+ 0.08%	25%	0.01%	0.5%

* Adjusted for changes in relative proportion of 'Mer x Mer' vs 'All Other' joinings

The key findings from Table 15 include:

- Over the period of SRRIP delivery there has been an average annual increase in the sheep death rate for all breeding systems of 0.09%.
- Removal of the 2017/18 year from the analysis results in an average annual decrease in sheep death rate over the SRRIP delivery period of 0.03%.
- The R^2 values indicate a large degree of variability in sheep death rate between years.

Table 16 presents the overall assessment of achievement against the various sheep reproduction KPIs reported in relevant industry strategic plans utilising available data presented above.

Table 16: Assessment of performance against sheep reproduction KPIs reported in various industry strategic plans

Key Performance Indicator	Strategic Plan	Achievement/Progress	Evidence
Increase net reproduction rate by 10 percentage points (annual increase of 2%)	SRRIP	Not achieved 	Table 13
Increase lamb marking rate by 5 percentage points by 2020 (Annual increase of 1%)	SISP	Depends which dataset is used 	Table 13. Likely fall in lamb marking rates in 2018/19 may reduce the overall annual gain to below the target by 2020
Decrease ewe mortality by 1 percentage point by 2020 (Annual decrease of 0.2%)	SISP	Not achieved 	Table 15. National time series data on ewe mortality is not available, however given that sheep mortality has increased it is assumed that ewe mortality would also have increased.
Increase merino lamb marking rate by 0.5 percentage points per year to 2030	WIRNS	Achachieved to date 	Table 13
Merino lamb survival rates increase by 0.2 percentage points per year to 2030	WIRNS	Likely to have been achieved to date but no specific evidence 	No national data on changes in lamb survival is available. Available data on scanning rates from WA (DPIRD) indicates a slight average increase in Merino scanning percentage of 1.5% p.a. between 2016 and 2019 but a decrease of 1.5% p.a. between 2017 and 2019 (Table 14). Given achievement of 1.0% p.a. increase in marking rate between 2012 and 2018, it is very likely that at least 0.2% of this increase is due to increased lamb survival as opposed to increased ewe fertility in Merinos.
Adult Merino sheep mortality is reduced by 0.1 percentage points per year to 2030 (0.13% for hoggets)	WIRNS	Not achieved to date 	Table 15. No national time series data is available on adult sheep mortality rate for Merinos, however given that mortality rate for all sheep post weaning has increased, it is assumed that adult Merino sheep mortality has also increased.
Proportion of hogget ewes mated (NB: interpreted by authors to mean ewe lambs) increases by 0.5% pa from 10% to 17.5% by 2030	WIRNS	Lack of data to assess with any accuracy 	Pre-LTEM survey data shows: 2016: 6% of Merino producers mated ewe lambs 2017: 11% of Merino producers mated ewe lambs No subsequent data is available from LTEM. MLA project P.PSH.1180 (milestone report 4) reported 7.5% of 388 Merino producers

Key Performance Indicator	Strategic Plan	Achievement/Progress	Evidence
			surveyed nationally joined ewe lambs in 2019 (or in the most recent normal season).
25% of Merino ewes are managed using LTEM recommendations by 2022	WIRNS	On target 	LTEM participant survey data: 6,817,803 participant Merino ewes/26,979,913 total Merino ewes (ABS)=25%. Assume some level of dis-adoption due to drought and lack of success and/or time to sustain practice so actual figure is likely to be currently less than 25%.
Number of Merino ewes scanned and differentially managed increases from 25% in 2016 to 34% by 2022	WIRNS	No national data to assess however LTEM data suggests this may already have been achieved. It is at any rate, likely to be on target. 	Pre-LTEM data showed: In 2016: 25% of Merino producers were scanning and managing ewes differentially (assumed this is where the 25% base came from) In 2017: proportion increased to 34% In 2018: it was 52%
Demonstration of continuous improvement in animal welfare	NAWRDE		Indirectly demonstrated via increased national weaning rate and via results from R&D, including PDSs, which demonstrate increased lamb survival outcomes.
Education, training and extension strategies are developed and implemented to deliver animal welfare R & D outcomes	NAWRDE		Refer to Table 9

Regardless of which dataset is utilised to measure success in the key sheep reproduction variable of number of lambs weaned (or marked as a proxy), the impact of seasonal variation on both conception and lamb survival can be considerable. While there are strategies for producers to decrease their exposure to seasonal variation, it will nonetheless impact on results for the extensive management systems in Australia. Therefore, setting a target level of performance in the context of likely seasonal impacts on this performance, without acknowledgement of, or any means of accounting for that variation in assessment of success or otherwise, is problematic.

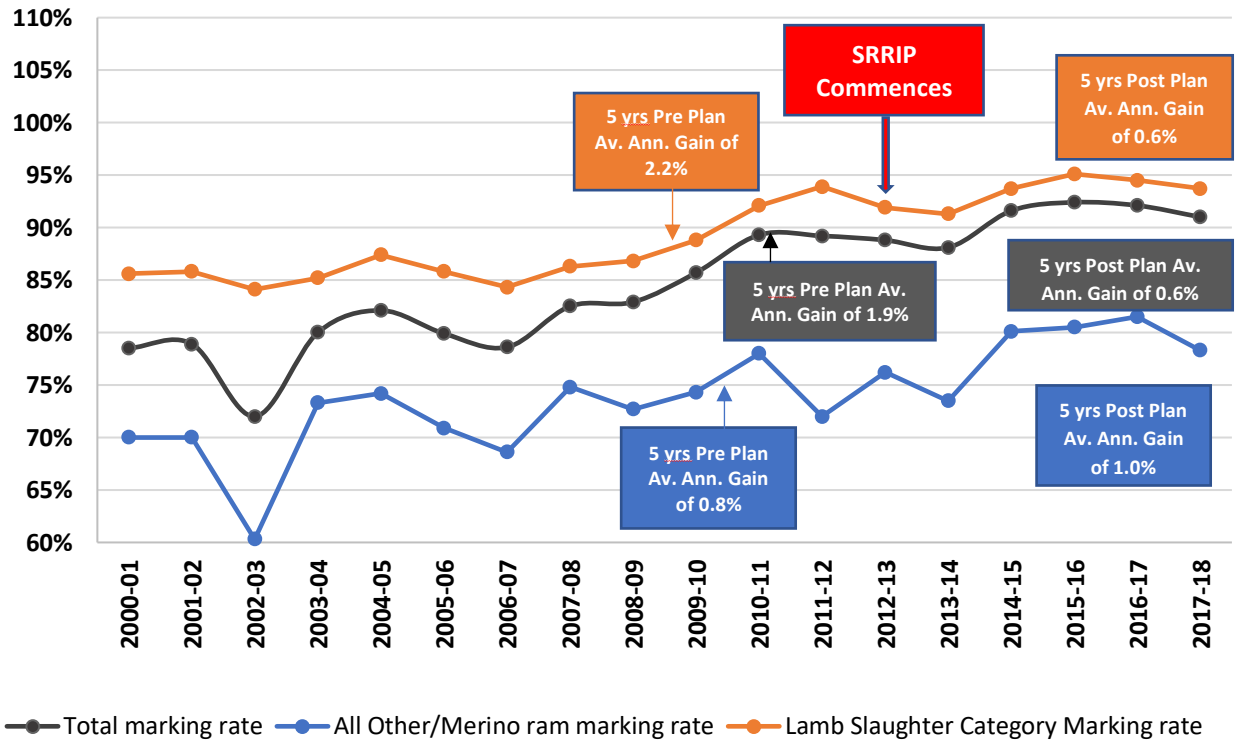


Figure 25: Long term national lamb marking rate data (ABARES Farm Surveys)

Figure 25 indicates a slowing of the average trend of increasing total lamb marking rates during the SRRIP implementation period compared to the five years prior. While the estimated annual gain in marking rate for all non-lamb slaughter enterprises increased during the SRRIP implementation period compared to the five years prior (+0.2% p.a.), a high degree of variability and therefore a relatively low R^2 value was associated with this trend (Table 13).

The data presented in Figure 26 illustrates the considerable difference in seasonal conditions during implementation of the SRRIP compared to the years prior, represented by rainfall deciles where the darkest blue at the top of the scale represents highest rainfall on record, and the darkest red at the bottom of the scale represents lowest rainfall on record.

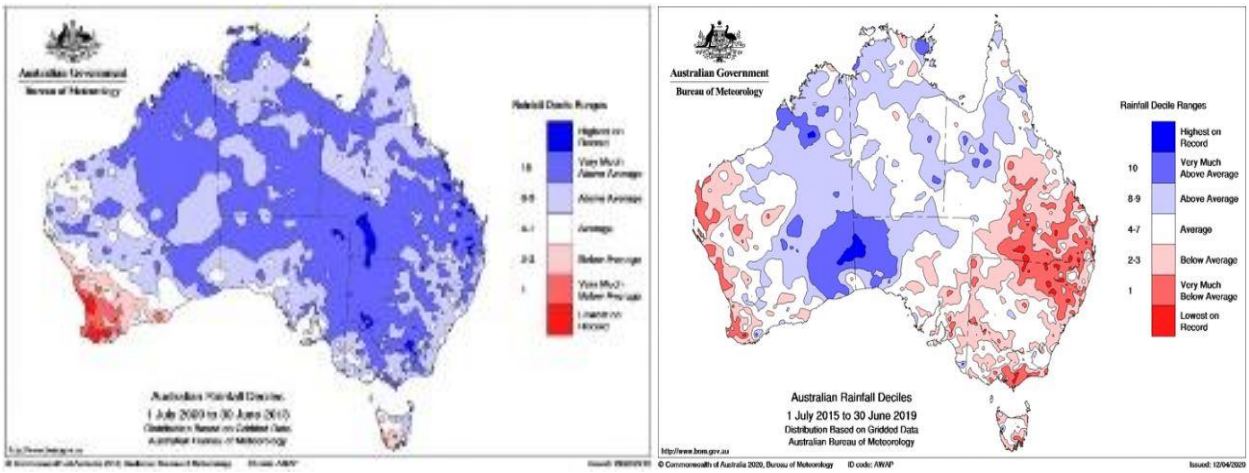


Figure 26: National rainfall decile data between July 2009 and June 2013 (left hand figure) and between July 2015 and June 2019 (right hand figure) (Source: BOM)

Data for summer mean temperature for the six years prior to the SRRIP and the six years post commencement of the plan illustrates a clear trend across all states with the exception of WA, of higher summer temperatures during the SRRIP implementation period (Figure 27). The impacts of increased summer temperatures on ewe conception and early embryo loss is less clear than the impacts of reduced rainfall on sheep productivity, however research has shown that heat stress could have a considerable impact on reproduction during the joining period, with further research into this issue currently underway.

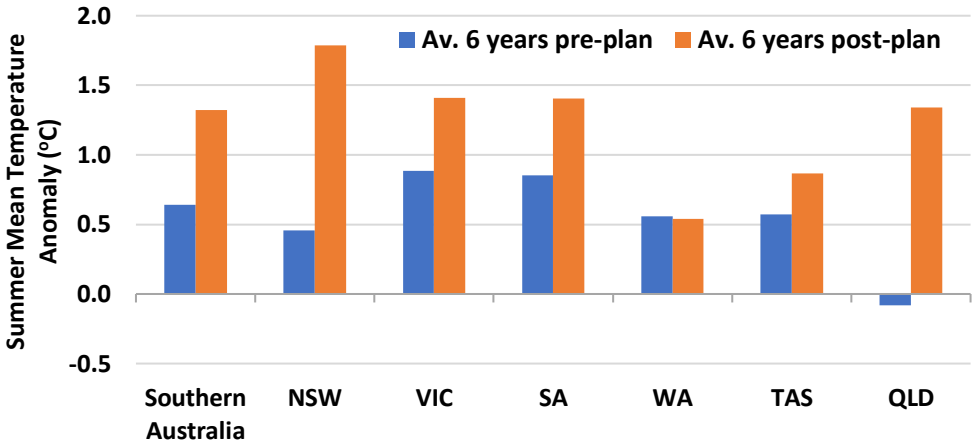


Figure 27: Average summer mean temperature anomaly for southern Australia by state for the six years prior to the SRRIP and during the six years of SRRIP implementation (Source: BOM)

Finding 24: *The SRRIP target of a 2% average annual increase in national lamb marking rate over the five-year investment period has not been met. The average rate of gain in marking rates during the SRRIP delivery period is likely to have been between 0.6% and 1.5% depending on the data source. This rate of gain is highly likely to have been negatively influenced by below average seasonal conditions over the SRRIP implementation period.*

It is also evident from long term temperature data that there has been a trend of increasing summer temperatures in southern Australia (Figure 28). While not all ewes are joined during the hotter summer months, it is likely that increasing temperatures in summer months is affecting a portion of the national flock, with this impact likely to increase further over time.

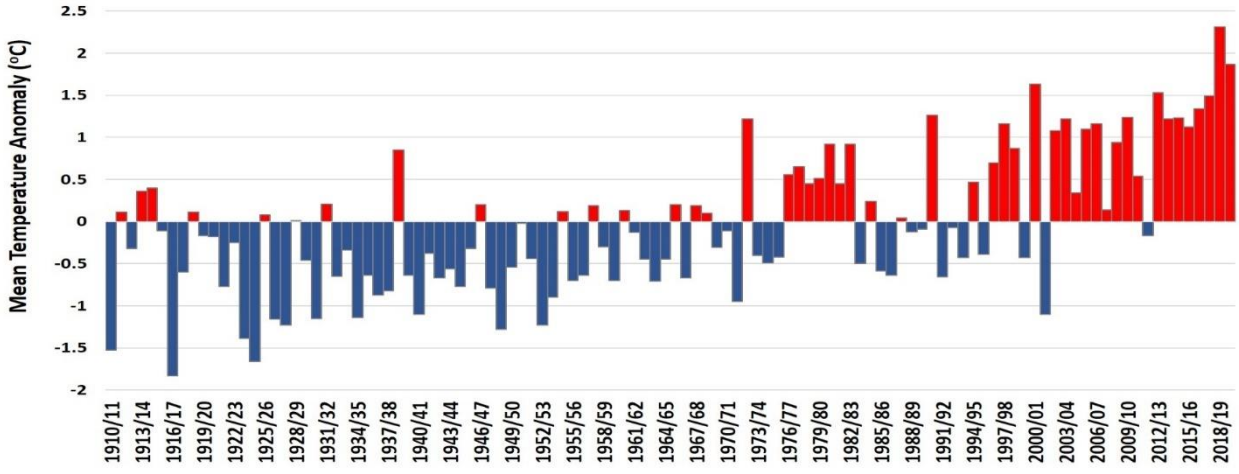


Figure 28: Historical mean summer temperature anomaly for southern Australia (Source: BOM)

Finding 25: *Seasonal variation has a considerable impact on ewe reproduction rate, particularly for Merino enterprises, which makes it difficult to accurately assess the impact of investment in RD&E on national sheep reproduction outcomes.*

Recommendation 11: *Given that climate variability is likely to increase in the future, MLA and AWI to consider investigating methods for modelling the impact of season on sheep reproduction rate in an effort to account for at least some of the seasonal influences on measured reproduction outcomes. This information may also assist with communication of efforts to improve animal welfare outcomes with consumers and the challenges associated with increasing lamb survival on farms.*

9.0 Product Impact Assessment

An inventory of 120 RD&E project investments were assessed during this review. Each project was allocated to one of 3 categories:

- Category 1: The project creates or contributes to an existing or new output (product) with directly attributable adoption outcomes and adoption related productivity impacts.
- Category 2: The project delivers tools and enabler type outputs that do not directly deliver attributable impact, but are necessary to support other products such as extension programs.
- Category 3: The project does not deliver an output (product) with attributable adoption outcomes or impacts, but should be funded for other reasons e.g. 'blue sky' research.

Projects allocated to Category 1 which were contracted between 2012/13 and 2016/17 were included in the assessment of economic impacts. An overview of each product assessed is provided below, with estimated impact provided as additional profit per ewe and benefit cost ratio (B:C ratio) based on estimates of producer adoption and total product investment (including cash and in-kind). A discount rate of 5% was utilised over a 25-year time horizon.

In conducting the impact assessments for each product, a consistent approach has been taken to the valuation of additional productivity gains, which typically involve value of additional lambs weaned and value of reduced ewe mortality, and to the costs associated with implementation of practice change. These assumptions are provided in Tables 17 and 18.

Table 17: Assumptions for valuing production benefits in terms of reduced ewe mortality and increased number of lambs weaned (NLW)

Parameter	Breeding System			Source
	Merino X Merino	Merino X Other	Other x Other	
Ewe weight (kg LW/Hd)	60	60	70-75	Author assumption
Average ewe micron	20	20	30	Author assumption
Cost of ewe mortality ($/Hd)	$155	$155	$144	Opportunity cost of ewe salvage value assuming: - Average 5 year real net value of $4.50/kg CW - Average 5 year 20 micron real net wool price of $16.62/kg Cl - Average 5 year 30 micron real net wool price of $6.73/kg Cl - Shearing cost of $7.15/Hd

Parameter	Breeding System			Source
	Merino X Merino	Merino X Other	Other x Other	
Lamb price ($/kg CW)	$6.54	$6.54	$6.54	5 year average real net lamb price
Value of an extra single lamb weaned ($/Hd)	$102	$114	$99	Extrapolated from Young *et al.* (2014) assuming a linear relationship between lamb price ($/kg CW) and lamb value ($/Hd) and adjusted for birth type rear type for twins (J. Young pers. comm.)
Value of extra twin lamb weaned ($/Hd)	$75	$100	$89	
Value of extra triplet lamb weaned ($/Hd)	$67	$67	$67	
Proportion of R&D reported impacts achieved by producers	Core producers (directly involved in trials) adopting achieve same production benefits reported from R&D and other producers adopting achieve 70% of production benefits reported from R&D.			Author assumption based on lower expertise and lack of consultant advice relative to on the demonstration/trial sites.
Actual vs potential achievement of genetic gain in NLW by commercial producers	70%			Author assumption based on assumption that commercial producers will not realise full potential genetic gains in NLW ASBV due to a range of environmental and management variables both within and outside of their control.

For extension products, the implementation cost of practice changes has been estimated utilising LTEM data as the most comprehensive source of participant evaluation data. Estimates have been made of the implementation and utilisation cost for a range of practice changes, with a weighted average cost calculated based on the number of ewes impacted by adoption of each type of practice change as reported in the LTEM participant evaluation database (Table 18). The weighted average cost is then multiplied by the ratio of the change in productivity for each project relative to that achieved for LTEM.

The cost associated with management of ewes to CS targets is the most difficult to value given that it will be dependent upon the base scenario, the season, joining/lambing time and stocking rate. For those producers identifying adoption of this practice, it is suggested that changes involving additional costs, as opposed to improved feed allocation practices, would most likely involve supplementation of multiple bearing ewes in late pregnancy for Autumn lambing flocks and supplementation of ewes pre-joining for Winter/Spring lambing flocks. It is also acknowledged that supplementation would not necessarily be required in all years. In the absence of any detailed information on what practices producers are actually adopting regarding supplementation, estimates have been made based on known additional energy requirements for multiple bearing ewes in late pregnancy and CS targets for joining, however these estimates are made within a very broad range of likely practices actually occurring on individual farms.

Table 18: Assumptions utilised for implementation and utilisation costs associated with key practice changes adopted by LTEM participants (2014-2019)

Practice Change	Implementation Cost ($/Ewe)	Assumptions
Condition Score (CS)	$0.23	Labour @$30/hr, CS 3 x per year, 50 ewes per mob, 30 minutes per 50 ewes, av. mob size of 200
Manage ewes to target CS	$3.75	Assumed multiple bearing ewes are supplemented for 6 weeks prior to lambing @ 200g/d for Autumn lambing flocks (40% of all flocks,

Practice Change	Implementation Cost ($/Ewe)	Assumptions
		MLA/AWI survey) in 50% of years and ewes are supplemented for 1 month prior to joining at 300g/hd for Winter/Spring lambing flocks (60% of all flocks, MLA/AWI survey) in 50% of years, wheat @ $302/T (5 yr average real feed wheat price ABARES). Additional labour for feeding out at 30 mins/mob/day @ $30/hr
Scanning Wet/Dry	$0.93	Scanning cost W/D of $0.65/ewe, scan 400 ewes/hr, labour @$30 hr, require av 2.5 people/day (2-3 depending on yard conditions), $300/day flat scanner callout rate
Scanning multiples	$1.30	Scanning cost for multiples of $0.85/ewe, scan 250 ewes/hr, labour @$30 hr, require av 2.5 people/day (2-3 depending on yard conditions), $300/day flat scanner callout rate
Feedtest samples	$0.07	Av 2.5 per farm (1-5 range) @ $64/test plus labour of 15 mins per sample collected @ $30/hr
Twin ewe management	$0.35	Assuming 50% of producers adopting differential management for multiple bearing ewes adopt smaller mob sizes at lambing. Cost of infrastructure to reduce mob size of $1.60/ewe (Temporary fencing PDS) assuming 40% multiple bearing ewes. Additional labour to manage twins separately of 1 hr per 1,000 ewes at $30/hr.
Assess FOO	$0.45	On average assess paddocks once per month, 15 mins per assessment, 200 ewes per mob, labour @$30/hr
Wet/dry ewes at marking	$1.50	Assuming 40 ewes/hr plus extra labour unit @$30/hr
Quantify ewe & lamb survival	$0.02	Half hour per 1,000 ewes @ $30/hr
Weighted average cost	$3.80	Based on number of ewes impacted by adoption of each practice change reported in LTEM participant survey database.

Where available, producer participant evaluation data has been utilised to estimate the change in productivity from practice change adoption, and where this data was not available, LTEM participant data has been utilised as the best available estimate of likely productivity improvement. ABARES data adjusted to account for the proportion of producers participating in extension activities was utilised to represent the counterfactual productivity scenario for extension programs, while experimental/trial control data was utilised for other products, including PDS projects.

Wherever relevant, a consistent approach has also been taken for assumptions relating to practice change adoption. While actual or intended practice change data was available for most, but not all, products, assumptions have been made regarding the translation of intended to actual practice change, the attribution of adoption to participation in the project/activity and the level of dis-adoption over time. While surveys of project participants were not undertaken as part of this evaluation process, findings from other participant survey data for adoption outcomes has been utilised as the basis for these assumptions. The key adoption assumptions utilised are provided in Table 19.

Table 19: Key assumptions utilised for practice change adoption

Assumption	Source
75% of producers stating an intention to adopt will adopt	Based on producer survey data collected by Howard *et al.* (2014)
78% of adoption is attributed to producer participation in the extension activity	Based on producer survey data collected by Beattie *et al.* (2019)

Assumption	Source
Dis-adoption of practice change commences 10 years post initial adoption at a rate of 5% p.a.	Author estimate to account for exits from the industry and substitution with new improved practices over time.
6.5% of producers initially adopting will dis-adopt 1-2 years later	Based on survey data collected for evaluation of the MMfS and MBfP programs by Howard *et al.* (2014) and It's Ewe Time participant survey data collected by Beattie *et al.* (2019)
An additional 5% adoption among local producers for on farm demonstration projects outside of direct involvement as either a core or observer producer	Author estimate to account for producer dissemination of trial benefits through local communities.
Producer benefits will commence in the financial year following program/project involvement	Author assumption based on types of practice changes adopted.
For genetics projects, a 3-year lag between genetic gains in the nucleus flock (i.e. stud/ram breeding sector) and benefits in commercial flocks	Represents lag between rams born in nucleus flock and lambs born in commercial flock.

It is important to note that some of the research and development products, including PDS projects, also contribute to impacts for extension products that have been counted as benefits for the latter rather than against the research/development project. For example, the direct benefit from the 'Temporary fencing for improved lamb survival' PDS project has been measured in terms of impact and adoption among producers directly involved in that project as core participants or observers, however the findings from that demonstration have also indirectly benefitted other producers via extension through products such as It's Ewe Time, Bredwell Fedwell, LTEM and Making More from Sheep, where the impact of adoption has been attributed directly to these extension programs.

It is very difficult to accurately attribute adoption to any one extension program given that producers typically build the knowledge, skills and confidence required to make practice changes over a period of time, utilising information and experiences from a range of extension activities and sources. Care should therefore be taken in comparing the relative net benefits reported for different extension products. Rather, it is the overall benefits attributed to all sheep reproduction extension activities collectively that is the most meaningful measure of return on industry investment.

9.1 Overview of Products

Conception and Early Embryo Mortality

9.1.1 Flushing ewes to increase conception

Estimated impact: None

The research for this product showed that flushing ewes by providing green feed one week prior to joining and one week into joining improved lambing percentage through an increase in multiple ovulations and ewes pregnant (Gaunt *et al*., 2017). Phase 1 found that around 60% of trial sites (13/22) recorded a significant increase in lambs scanned per ewe (additional 10-33 per 100 ewes) compared to grazing on typical dry feed. Phase 2 found that around 38% of trial sites (3/8) recorded significant increases in scanning rates ranging between 16 and 47 more lambs per 100 ewes joined (Gaunt *et al*., 2017). The researchers concluded that the information obtained suggested no negative impact on ewe

reproductive efficiency when grazing on lucerne throughout joining compared to a short flush or grazing on typical dry pasture.

The researcher for this product indicated that no follow-up evaluation was conducted with producers involved in the trial to determine intention to use, or actual usage, of flushing as a seasonal tactic or regular practice to increase lamb marking rates (G. Gaunt, pers. comm.). It was noted that there was one article in the MLA Feedback Magazine presenting the results from this research, but beyond that, no further extension of project findings was delivered to industry (G. Gaunt pers. comm.).

Given the absence of a targeted adoption pathway for the results from this project, the relatively small number of producers involved in the trial and the unknown level of adoption among these producers, it has been concluded that there is no measurable on farm impact for producers from this product investment.

9.1.2 Fertility of sexed ram semen

Estimated impact: None

Research into increasing the fertility of artificial insemination (AI) with sexed ram semen culminated in the commercial availability of this technology in 2018. The sexing semen technology is currently only provided by one company in Australia, Total Livestock Genetics (TLG), in Victoria. Researchers concluded that while sex sorted spermatozoa can be used following a short period of liquid storage (up to 24 hours post semen collection), that fertility will be compromised to some degree (Rickard and de Graaf, 2018).

Although the technology for sexed ram semen is currently available to producers, there has been next to no adoption in Australia to date (S. Williams, TLG, pers. comm.). According to TLG, uptake of the technology has been negligible due in part to a lack of promotion and therefore awareness of the technique, and partly due to the increased riskiness and higher cost of the technology relative to traditional AI. At present, the technology requires use of fresh semen and quarantining of rams for 30 days at the Camperdown facility. This requirement limits the practicality of utilising the technology for many producers, in addition to increasing costs of accessing the technique.

TLG does not offer laparoscopic AI services, therefore the sexing semen technology is not a core part of their business and as such has not been promoted to producers (S. Williams, TLG, pers. comm.). It is suggested that other commercial AI providers are unlikely to have promoted use of the technology among their clients due to the increased risks associated with expected outcomes and how this may reflect on the provider, and that providers typically have their own processes and channels in place to provide semen that would be diluted by involving a third party required for accessing the sexed ram semen technology.

It is unknown as to whether or not utilisation of the sexing semen technology will increase over time, however it would likely only be utilised over a short period of time by studs wanting to increase ewe numbers rapidly for new breeds (e.g. Australian Whites), or possibly by a small number of studs wishing to increase ram numbers in a portion of their ewe flock. In either case potential adoption would only represent a very boutique practice among a very small number of Australian sheep producers (S. Williams, TLG, pers. comm.).

For the current impact assessment, it has therefore been concluded that this product has had no measurable impact on producers. The technique does however provide the technology to rapidly increase ewe numbers in the event of a situation where a radical change in genotype is required across a broad proportion of the Australian flock, and thereby provides an insurance against potential major disruptions to national wool and lamb production.

Ewe Nutrition (Diet/Supplements)

9.1.3 Metabolic disorders in pregnant and lambing ewes

Estimated impact: None

This product involved investment in three projects: 'Failsafe guides to grazing pregnant and lambing ewes on cereal Phase I and Phase II' and 'Managing metabolic disorders in pregnant ewes'.

Results from the 'Failsafe guides to grazing pregnant and lambing ewes on cereal' research identified that crops (particularly wheat grown in NSW) provided ewes with an unbalanced mineral supply of low Calcium (Ca), Magnesium (Mg) and Sodium (Na) accompanied by high Potassium (K) (Masters *et al*., 2017). This combination was found to increase the risk of hypocalcaemia and hypomagnesaemia. Partially consistent with this observation, ewes grazing crops had a low Ca status but did not show clear signs of low Mg status. The project did not measure any impacts of mineral deficiency or supplementation on ewe or lamb survival.

In consultation with the researchers involved in delivery of this project, it was concluded that while there was value in increased knowledge generated from the research, it did not generate any clear adoptable outcomes that could provide a measurable impact on ewe or lamb survival, and subsequent ewe reproductive rate. Thus, for the current impact assessment, this project is considered to have generated no measurable impact on producers.

Research for the 'Managing metabolic disorders in pregnant ewes' project involved monitoring of 16 lambing flocks across NSW, SA, Victoria and WA in 2016, and demonstrated that a third of flocks had more than 20% of ewes with below adequate Ca or Mg concentrations a week before lambing when grazing typical pastures (Friend *et al.*, 2018). An intensive pen study with twin bearing ewes showed that although the Ca and mineral status of ewes did not significantly alter the duration of parturition, supplementation with minerals did improve energy regulation in the ewe, potentially enabling the ewe to maintain health in less optimal conditions. Furthermore, mineral supplementation improved the immune response in both ewes and lambs, proving a mechanism through which lamb survival might be altered. Lamb weight at 4 weeks of age was also improved by supplementation. The pen study did not contain sufficient ewes to measure lamb survival, so the impact of supplementation was tested in grazing ewes on commercial properties.

In 2017, a replicated study used 5 flocks (across NSW, SA, and WA) with control and supplemented groups. It was concluded by the researchers that mineral supplementation alone may not result in significant increases in lamb survival in individual flocks when ewes are grazing common pastures, however it was recommended as a low-cost risk management strategy for pregnant ewes (especially twin bearers) (Masters *et al*., 2018). The recommended practice was to provide a loose mix of lime/causmag/salt in a ratio of 1:1:1 fed daily in a grain mix at 20g per ewe for 6 weeks at a cost of around 2c/ewe/day.

Over the recommended feeding period of 6 weeks (2 weeks pre-lambing and 4 weeks post lambing), the total cost is around $0.84 per ewe, but this cost does not include labour and other costs associated with mixing and feeding these supplements out on a regular basis, which could be considerable depending on existing supplementary feeding practices. It is therefore suggested that unless lamb price is very high and/or the risk avoided is high, the potential return on investment from this recommended strategy for individual producers is likely to be low, particularly if additional time and effort is required for implementation.

Based on these findings, for the current impact assessment it was concluded that while the research generated new knowledge and understanding of metabolic disorders in pregnant ewes, it did not generate any clear adoptable outcomes that could provide a measurable impact on improving ewe or lamb survival.

Lamb Survival (Management)

9.1.4 Improving lamb survival through lambing density and mob size

Estimated impact: $1.59/ewe and B:C Ratio of 1.1

This project aimed to quantify the effects of mob size and stocking rate on the survival of Merino and non-Merino lambs born across southern Australia to deliver improved recommendations for sheep producers. The project also aimed to assist producers to make more informed decisions about the cost-benefit of investing funds in paddock subdivision through permanent or temporary fencing to improve reproductive performance and farm profitability.

The research involved three components which were completed across southern Australia; (i) on-farm research at 70 commercial farms to test a 2x2 factorial combination of mob size (high or low) and stocking rate (high or low) on the survival of twin-born lambs of Merino or non-Merino breed; (ii) on-farm research at 15 commercial farms to test the effect of mob size (high or low) on the survival of twin-born Merino lambs at low stocking rates; and (iii) a network of 194 sheep producers who contributed data for 2,174 lambing mobs from their own farms to investigate the impacts of mob size and stocking rate on the survival of single- and twin-born lambs of Merino and non-Merino breed across a broad range of management and environmental conditions. The key outcome from the project in terms of lamb survival was that reducing mob size by 100 ewes increased survival of twin-born lambs by 1.1% to 2.5%, regardless of breed, when stocking rate typically ranged from 1.5 to 12.5 ewes/ha. The current assessment did not include valuation of any potential benefits of improved pasture utilisation due to reduced paddock size.

9.1.5 Foetal aging for increased lamb survival

Estimated impact: None

The objectives of this project were to assess the impact of sire on estimates of foetal age by scanning when AI date and therefore true foetal age are known, and the impact of lamb/dam genotype, ewe parity and litter size on the calibration curves required to estimate foetal age, with the intention of obtaining more accurate calibration curves for industry adoption (from a new ewe resource population). The project met both these objectives, and also provided some clear indication of how accurately ewes can be assigned to lambing groups in commercial flocks using current methods for foetal aging.

According to the researcher (K. Bunter (UNE) pers. comm.), foetal aging has not been incorporated into the genetic evaluation system as there is currently no effective data capture for this trait, and breeders are not routinely requesting it. It was suggested that there is a need to demonstrate to producers how not knowing the age of an animal influences the accuracy of breeding values. This could motivate producers to improve recording generally, including identification of how to obtain more accurate data on age, via scanning or otherwise.

The overall extension message generated from this project was that foetal aging can be used with around 80% accuracy in commercial flocks to split ewe mobs into three lambing groups based on expected time of lambing, with the accuracy increasing to 100% for splitting ewes into early and late lambing mobs. This message was delivered via an awareness of research results reported in various articles and podcasts (The Land, Sheep Connect, The Yarn, Sheep Central, Farm Tender). The message did not involve presentation of a value proposition for producers in terms of reporting of any costs or quantifying any potential benefits associated with the practice. As far as the authors are aware, this information does not exist, however may be part of the outcomes from the current MLA project: Increasing lambing percentages through better use of pregnancy scanning technology. Also, as far as the authors are aware, foetal aging is not specifically promoted in the key extension programs, including LTEM, It's Ewe Time, Bredwell Fedwell or Picking Performer Ewes, although it may be discussed informally during these events if raised by participants.

According to co-researcher, D. Fowler (Australian Livestock Scanning Service Group Pty Ltd) pers. comm., there has been new adoption of the technique due to this project but only directly via ALSS clients, however this adoption only represents a very minimal proportion of ewes nationally. It was also noted that the number of ewes scanned for foetal age has declined by around 30% over the past 12 months due to impacts of the drought (D. Fowler, pers. comm.). Broader adoption is currently limited due to a lack of suitably skilled scanning technicians and no progress toward development of an automated technique for assessing foetal age, in addition to lack of a clear value proposition for producers.

For the current impact assessment, it has therefore been concluded that there has been no measurable impact on producers from this project given the minimal ewe numbers impacted directly via ALSS. However, it does appear that there is scope to increase adoption via development and extension of a clear value proposition for adoption, and investment in development of an automated technique for delivery of the practice to increase accessibility and accuracy for producers, however this would need to be provided cost effectively to facilitate adoption.

Adoption

9.1.6 Merinos to Market/Realising Performance Potential

Estimated impact: $0.96/ewe and B:C Ratio of 2.9

The Merinos to Market (M2M) workshop was developed during 2015/16 to target both stud and commercial Merino producers to improve the management of ewe flocks and encourage participation in LTEM. The workshop was designed as an alternative to BWFW, with less focus on genetics. A key segment of the market to be targeted by M2M was ram breeders not using breeding values that had been ineligible to host a BWFW workshop but had interest in improving the ewe management among

their commercial clients. Between August and November 2016, AWI ran 5 pilot M2M workshops and followed on with a further 11 workshops renamed as Realising Performance Potential (RPP) between May and July 2017.

The objective of these workshops was two-fold:

- Drive participation in LTEM to facilitate increased application of condition scoring, scanning for multiples, and feed budgeting to achieve reproduction outcomes; and
- For LTEM alumni, to complement the LTEM-taught ewe management approach with practical ewe selection practices (wet/dry at lamb marking).

Based on positive participant feedback collected from these workshops, a subsequent workshop was developed, called Picking Performer Ewes (PPE). The content for the PPE workshop is in the process of being finalised with delivery likely to commence later in 2020.

Participant feedback was collected from the workshops held, which included participant intent to adopt specific practices, however no follow-up data or impact data for these practice change intentions was collected. Participant survey data collected post workshop provided information regarding the intended level of practice change for a range of areas. These were slightly different for the M2M and the RPP participant data sets, but included:

- Scan for multiples
- Wet/dry at marking
- Lambed and lost
- Better culling of non-productive ewes
- Keeping older performing ewes

In terms of assessing the impacts of these intended practice changes, it was assumed that wet/drying ewes at marking, assessing ewes lambed and lost and keeping older performing ewes were all practices that would assist with improved culling of non-productive ewes to ultimately generate a financial benefit for the producer. Thus, the two practice changes evaluated for this assessment were scanning for multiples and improved culling of non-productive ewes.

9.1.7 Lifetime Ewe Management

Estimated impact: $0.66/ewe and B:C Ratio: 8.5

Lifetime Ewe Management (LTEM) is designed to assist producers to improve their understanding of ewe nutrition and to develop the skills and confidence to improve their management. The program was developed by Rural Industry Skills Training (RIST) and the then Victorian Department of Primary Industries based on a combination of findings from the Lifetime Wool (LTW) project and the Victorian paired-paddock program (Triple P).

The objectives of LTEM are to:

- Improve producer understanding of the impact of ewe condition and nutrition on ewe and progeny performance;
- Develop producer skills and confidence to adopt LTW management guidelines; and

- Demonstrate on participating properties with their sheep that the guidelines developed by LTW for the management of ewes and their progeny are practical and profitable.

Program delivery involves groups of 4 to 6 producers meeting for 6 sessions over a 12-month period facilitated by an expert in sheep production and extension. Group members visit each participating farm and learn skills in condition scoring, pasture assessment and best practice ewe and lamb management to increase reproduction efficiency and wool production, mainly through reducing ewe and lamb mortality. After piloting in 2005/06, the program has since involved almost 4,000 participating businesses representing around a third of the national ewe flock. For the current impact assessment only outcomes for participants graduating from the program between 2014 (commenced 2012/13) to 2019 (commenced 2017/18) have been included.

9.1.8 It's Ewe Time

Estimated impact: $0.48/ewe and B:C Ratio of 5.8

It's Ewe Time is a half day forum aimed at creating awareness of key issues, MLA and AWI programs, best practice and new research data. It is run in conjunction with AWI and utilises leading industry experts and consultants to deliver key messages. Participants are sign-posted to other programs and sources of information for follow up afterwards. It is considered to be a 'feeder activity' to other programs i.e. creates awareness and appetite for other AWI/MLA programs.

It's Ewe Time forums had previously been held as part of Making More from Sheep and were considered a good vehicle for promoting MLA/AWI due to their previous popularity and reach. The program was reinstated in 2017 and since then (2017-2019) 1,113 people (820 producers) have participated in 23 forums, across the sheep producing regions of Australia.

9.1.9 Bredwell Fedwell

Estimated impact: $0.53/ewe and B:C Ratio of 8.3

Bredwell Fedwell (BWFW) is a practical, one day workshop focused on the key production benefits of genetics with improved feed management to improve reproduction. It focuses on the importance of combining genetics and feed management to enable optimal improvement in performance and therefore farm profit. The BWFW Sheep workshops allow producers to explore the usefulness of genetic tools (ASBVs and indexes) combined with setting of breeding objectives and best practice feeding of ewes to achieve optimal reproductive performance in their enterprises.

BWFW Sheep commenced in December 2011 and in one year delivered 58 workshops across the nation, including 8 pilots, to 1,600 participants. In Phase 2 (May 2012 to July 2014) a further 49 workshops were delivered with a total of 1,253 participants having attended the workshop, taking the overall total to 107 workshops and 2,853 participants. In Phase 3 (August 2014 to July 2015) 24 workshops were delivered to 470 participants. Phase 4 of delivery has involved 1,007 participants from 625 businesses in 53 BW FW Sheep workshops across Australia. For the current evaluation period, only Phases 2, 3 and 4 have been included as fitting within the timeframe for the impact assessment.

9.1.10 RAMping Up Repro

Estimated impact: $0.99/ewe and B:C Ratio: 112.5

RAMping Up Repro (RUR) is a hands-on half day workshop focussed on improving ram performance and working longevity in commercial sheep enterprises. The workshop is designed to increase the skill of producers across the key components of ram performance and impacts on overall breeding enterprise performance, including: Anatomy, Physiology, Spermatogenesis, Metabolic demands, Health, disease & biosecurity, and Financial impact of the ram team. Each participant is guided through a thorough pre-joining ram inspection by an accredited workshop deliverer and given the opportunity to increase their practical skills to undertake this in their own operation. The workshop is designed to give attendees the confidence to incorporate these skills into their own routine management, thus improving the performance of their rams. Five pilot RUR workshops were run in early 2017, and since then a total of 34 workshops and one online workshop have been delivered.

The high B:C ratio for this product is due to the very low investment cost relative to the number of producers impacted through delivery. The impact per ewe is based on self-reported whole farm economic benefits provided by producers in post event surveys minus estimated implementation costs. It is suggested that these self-reported benefits may be over-stated and thus some follow-up case studies with participating producers would be valuable for any future impact assessments of this program.

9.1.11 Profitable Grazing Systems - Lifting Lamb Survival

Estimated impact: $1.13/ewe and B:C Ratio: 2.7

Profitable Grazing Systems (PGS) is a group-based delivery program, funded by MLA, which drives improved business performance outcomes for participating red meat producers with measurable impacts. The program takes a whole-of-farm business approach to improve key profit drivers and overall business performance. It enables industry best practice and new research findings to be customised to local environments and farming systems. The PGS project was developed and approved by the MLA board following a pilot phase conducted in 2016. It should be noted that while there was some in-kind funding contribution to this product by industry, it was unable to be quantified for inclusion in this assessment.

The Lifting Lamb Survival course was designed to give producers the knowledge and skills to better manage lambing with the primary aim of improving lamb survival by optimising whole farm resource allocation. This requires specific attention to management between total flock scanning and lamb marking, with a major focus given to preparing the ewes and their lambing paddocks to enable better paddock allocation for lambing.

There were four pilots completed for the Lifting Lamb Survival (Lambs Alive) course in Victoria during 2016 involving 46 participants from 38 businesses. Since then, a further 6 Lifting Lamb Survival Supported Learning Projects (SLPs) have been delivered (4 in Victoria, 1 in SA and 1 in Tasmania).

9.1.12 Making More from Sheep – Reproduction only

Estimated impact: $0.99/ewe and B:C Ratio: 5.2

Making More from Sheep (MMfS) is a best practice package of management information and tools for sheep producers, developed by MLA and AWI. The package includes 12 linked online modules, which cover a range of topics including soils and pasture, wool and marketing, animal health, genetics, reproduction and farm sustainability.

For this impact assessment, estimated impact from sheep reproduction practice change only has been assessed. It has been estimated that 50% of all Making More from Sheep investment relates to delivery of sheep reproduction impacts based on findings from the impact assessment of MMfS Phase II, that 51% of all benefits attributed to MMfS were due to improved animal production, with most of the animal production practice changes relating to improved ewe management and lamb survival (Beattie and Howard, 2013).

9.1.13 Producer Demonstration Sites

Estimated impact: $2.78/ewe and B:C Ratio: 8.9

Producer Demonstration Sites (PDS) aim to increase the rate of adoption of key management practices and technologies that improve business profitability, productivity and sustainability. This is achieved through supporting livestock producers working in peer to peer groups to pursue new skills, knowledge and management practices applicable to their own commercial livestock production systems. The key outcome of a PDS is adoption of the demonstrated management practices resulting in improved business performance. Six PDS projects were assessed for this review and are discussed below.

9.1.13.1 Measuring Behaviour to Improve Maternal Ability

This project aimed to test the findings of two previous research station projects on the impact of maternal behaviour on lamb survival in commercial flocks. The previous research utilised an arena test to assess the reaction of a sheep to the attraction of a group of sheep and the repulsion of a human. The conclusion was that the test indicated a greater tolerance of the higher fertility sheep to isolation from a flock, indicating this may be a desirable trait at the birth site to reduce mismothering.

The project results did not demonstrate a relationship between any of the arena behaviour measurements and lambs weaned per lambing. The researchers concluded there were no economic benefits generated from the project and no practice changes to recommend to producers (Kilgour and Joshua, 2015). Thus, for the current impact assessment, this project is considered to have generated no measurable impact on producers.

9.1.13.2 Shelter Options for Increased Lamb Survival

The aim of this project was to demonstrate the establishment and measure benefits of different shelter types for lamb survival. Tall wheat grass (TWG), the leguminous shrub *Dorycnium hirstum* and constructed shelters including hay bales and corrugated iron structures were utilised as shelter types. Opportunistically, the third and fourth years of the project demonstrated the use of eucalypt plantations. The demonstration was conducted over four years with the Avoca, Casterton and Cavendish Best Wool Best Lamb groups, using eight sites provided by the groups in South West Victoria.

9.1.13.3 Nutritional Manipulation of Sex Ratio

Trials conducted by NSW DPI at the Wagga Wagga Agricultural Institute indicated that the proportion of female lambs was higher when ewes were fed oats and cottonseed meal compared with silage around joining. The aim of this project was to determine whether these results could be replicated in commercial sheep enterprises.

Results over the three years were variable between properties and between years. Overall, the study found that the proportion of female lambs at marking was 1.5% higher when ewes were fed grain in addition to pasture (53.3%) compared with pasture only (51.8%), however this result was not statistically significant (Clayton and Stringer, 2019). On three properties, the proportion of female lambs was between 4.1-4.8% higher when ewes were fed grain and on two properties the proportion of females was between 4.1-7.2% lower when ewes were fed grain around joining.

It was concluded by the researchers that the mean change in sex ratio observed was unlikely to lead to an economic benefit from feeding grain around joining (Clayton and Stringer, 2019). The majority of producers surveyed throughout and at the end of the project indicated that they were not convinced to consider changes as a result of the project findings. Thus, for the current impact assessment, this project is considered to have generated no measurable impact on producers.

9.1.13.4 Temporary Fencing for Improved Lamb Survival

The aim of this project was to determine whether or not temporary fences improve twin lamb survival and reduce mis-mothering by reducing mob and paddock size. The project involved running a trial over a three-year period with members of the Willaura BWBL Group in Victoria between 2017 and 2020. The benefits of the trial were measured in terms of differences in lamb marking percentages between paddocks that were split with fencing compared to those that ran the same/similar total number of ewes in an unsplit paddock of the same area. The project is still in progress and is due for completion in August 2020.

9.1.13.5 Chaff carts as sheep management tools

Trials in WA have previously demonstrated that grazing chaff carts piles can help reduce the summer-autumn feed gap, which is essentially a 6-month drought for WA sheep producers (Riggall, 2017). The process involves towing chaff carts behind harvesters during harvest as a weed control tool, and depositing chaff in piles rather than spreading it across the paddock. Depositing chaff in piles makes it more accessible to sheep, in addition to maintaining quality for longer compared to chaff spread across the paddock by traditional harvesting methods. Trials over the last two years in nearby shires demonstrated that sheep grazing chaff piles over a six-week period had significantly greater weight gain than those that had not, however many producers in the area do not use chaff carts (Riggall, 2017).

The purpose of the PDS was to demonstrate the benefit of better utilization of a feed source already on farm, a by-product of the cropping system, as an environmentally friendly solution that could reduce feed costs and increase production potential of sheep flocks on mixed enterprises in many regions. The specific aims of the PDS were to:

- Demonstrate that chaff carts can benefit sheep enterprises by increasing sheep condition (and marking rate) and reducing supplementary feed costs, improving overall farm productivity and profitability; and
- Foster a better understanding of the use of chaff carts for sheep management, and other sheep management tools such as condition scoring.

9.1.13.6 Good Clover Bad Clover

The Good Clover Bad Clover project aimed to address identified problems with oestrogenic clovers on properties in the South East of SA and Kangaroo Island by increasing the awareness of producers to the presence of oestrogenic sub clovers in their pastures and providing a measure of their severity and extent on property across districts.

The project commenced in April 2017 and involved coaching producers from 10 focus farms across Kangaroo Island and the South East of SA in the identification of oestrogenic clovers and the development of management plans and strategies for their properties. Paddocks on the focus farms were assessed using visual and laboratory analysis. Field days were held in the South East of South Australia and Kangaroo Island to train a network of other producers in identification and management of oestrogenic clovers on their own properties.

Applications for Sensor Technology

9.1.14 Sensor technology for establishment of maternal pedigree

Estimated impact: None

Research for this product involved measurement of the success of proximity sensors to match lambs to ewes with 40 flocks involving more than 15,000 ewes and lambs across southern Australia. Overall, the average success of matching a lamb to a ewe was 94.7% across the 40 flocks, and this increased to 96.4% after removal of three farms in which there were known problems with the protocol (Thompson *et al*., 2018). The success rate was 97.3% across 20 farms that used lambing rounds or DNA to establish dam pedigree.

The results demonstrated that proximity sensors can rapidly and accurately establish maternal pedigree and that the method is robust across a range of conditions experienced on commercial farms. The cost to identify the maternal pedigree of a lamb using proximity sensors was estimated at between $9 and $11 per lamb (Thompson *et al*., 2018). It was considered that a range of lower cost products would be in the market place within three to five years, and while it was noted that this technology should ultimately enhance recording of dam pedigree, and hence the rate of genetic gain across the sheep industry, that to achieve this the sheep industry requires a much clearer and more convincing value proposition for collecting dam pedigree at both the stud and commercial level.

In assessing the impact of this product on sheep reproduction outcomes for the current review, the following conclusions were made:

- As far as the authors are aware, there is no data currently being provided to producers around the value proposition for use of sensors for establishment of maternal pedigree;

- As far as the authors are aware, there is only one commercial sensor product on the market, retailing sensors for around $15 per unit. This product, marketed by Smart Shepherd, has been on the market since 2018;
- It is unlikely that the results from this project had any influence on the activities of current commercial providers of sensor technology for this purpose in terms of either timing or functionality of their product, however it may have provided some additional confidence to those developers in earlier stages of product development, including development of the AWI Smart Tag;
- Participation in the trials for this project is likely to have influenced the decision of some studs to adopt the sensor technology when it subsequently became commercially available, however as to whether these studs would have still adopted at some point is unknown, as is the number of studs adopting, the benefits attributed to adoption and the influence that involvement in this project may have had on the adoption decision; and
- Adoption of this technology is currently being driven via the private sector through a partnership between Smart Shepherd and Sheep Matters consultancy service for the latter to coordinate the service delivery of the technology for all new customers.

In considering the above information, it was concluded that there has been no measurable impact on sheep reproduction outcomes from this product.

Genetics

9.1.15 Genetic Gains in Sheep Reproduction Rate[1]

Estimated impact[2]: B:C Ratio: 2.2

There were six individual projects reviewed for this product, and due to the difficulty of accurately quantifying the contribution of individual projects, the impact of total investment has been assessed collectively for all project investments. Where project outcomes included other benefits that did not relate to sheep reproduction (e.g. wool and carcase traits) an estimate of the proportion of investment related to sheep reproduction outcomes has been made in consultation with project managers.

The impact has been assessed in terms of the value of genetic improvement in overall reproduction rate, represented by gains in number of lambs weaned (NLW), relative to what is estimated to have occurred in the absence of investment in RD&E (counterfactual scenario). Improvements in NLW may be achieved via improvements in one or more components of overall reproduction rate, and in overall reproduction rate itself.

A model was developed to capture the flow of industry benefits from the nucleus flock (i.e. the stud or ram-breeding sector) through to commercial producers over time. These benefits are captured in terms of changes in weaning rates over time, accounting for the number of ewes mated per ram lifetime and the ewe replacement rate, and valuation of the overall profit associated with increasing reproductive rate. These benefits are cumulative over time and are assumed to be permanent. The cost of utilisation

[1] The authors gratefully acknowledge the information and advice provided by Dr. Daniel Brown and Dr. Robert Banks (AGBU) in conducting this product impact assessment.

[2] A value for net benefit per ewe has not been provided as the net benefit is cumulative over time in alignment with incremental genetic gains.

associated with NLW breeding values above that incurred for other traits recorded per animal is considered to be negligible, and has therefore not been valued for this analysis.

Estimates of genetic gains in NLW have been made utilising five-year average rates of gain pre and post investment utilising Sheep Genetics data for the counterfactual and with investment scenarios respectively. Separate analyses were undertaken for Merino and Maternal systems. Sheep Genetics data on number of rams (Merino and Maternal) entering the industry by year with a record for NLW (accuracy above 40%) has been utilised to provide estimates of adoption in terms of number of ewes impacted each year, noting that full data is only available up until 2017 due to the lag in ram records entering the system.

The number of animals entering the industry with records for NLW has increased on average between 2015 and 2017 for Maternals, however this rate of increase has slowed relative to that for the years prior to 2015. The number of Merino rams entering the industry with records for NLW has decreased between 2015 and 2017. The slower rate of increase for the Maternals and the decrease for the Merinos over the past three years is most likely due to lower ewe numbers over that time. Given that these trends are not considered to be due to any impacts of RD&E, the average level of adoption during the delivery period has been utilised for both the 'with' and 'without' (counterfactual) investment scenarios (i.e. assuming a steady state in terms of average number of animals with records for NLW entering the industry each year).

An assessment has been made on conversion of potential to actual gains on farm and attribution of producer gains from changes in trends of genetic improvement over time to the R&D investment included in the current assessment period, acknowledging that additional investment has also occurred which has not been captured in the specific projects assessed for this review.

A summary of the six genetics project investments included in the assessment is provided below.

9.1.15.1 Pathway to Genetic Gains in the Number of Lambs Weaned in Merinos

This project aimed to work with industry flocks to vastly improve the amount and quality of data and depth of knowledge surrounding the genetic variation in reproduction and its component traits in the Australian Merino population. The project piloted the identification and demonstration of approaches that could be more widely implemented to ensure selection decisions are improving the reproductive potential of the Merino ewe flock including:

- Breeder-client forums
- Reproduction decision support tools (DST)
- One on one support
- Proximity devices to capture reproduction information

The project aimed to achieve these objectives by working closely with collaborating stud breeders, commercial producers and service providers to develop systems that are intuitive, practical and acceptable to a wide audience. If successful, the intention was to expand the pilot into a wider extension package taking forward key learnings from the project.

Researchers reported that the range of methods piloted to increase the collection and use of reproduction data varied considerably in their success. The following overall findings from the project were identified (Ferguson *et al*., 2019):

- The project has highlighted dam pedigree as the major limitation to uptake of reproduction breeding values in the merino sector. The scale of some of the Australian stud flocks is definitely a factor and the AWI Smart Tags should be deployed to industry as soon as is practical to help provide maternal pedigree information.

- There are some issues with software use which were assumed to be one of the major roadblocks for NLW within Australia. These issues can be overcome if we are given access to the relevant data. However, for the average stud breeder, utilising the software themselves, there are a number of potential problems which often result in the appropriate data not getting to Sheep Genetics. It is hoped that the recent changes to the maternal analysis, once mirrored in the Merino analysis, will provide the necessary clarity for stud breeders and software providers.

- Stud producers contacted to be involved in collecting the required information were largely uninterested/unwilling or unable to provide the required information.

- The analysis of the Merinotech WA database proved to be a much larger job than anticipated, while the decision support tool was not pursued, the analysis has been very worthwhile and paves the way for much more detailed analysis and economic modelling. Importantly, the analysis shows the rate of gain that can be made in NLW while simultaneously making a good rate of genetic gain in other objective and subjective traits.

Key project recommendations included:

1. Industry wide roll out of the workshops piloted during the project
2. Commercialisation of AWI Smart Tags for dam to lamb mothering
3. Industry wide release of the booklet developed during the project
4. MLP fixed effect data analysis and scenario modelling

Discussion with the project deliverer, M. Ferguson (NextGen Agri) pers. comm., identified that while there was likely to have been some level of practice change among the studs which hosted the pilot workshops and the producers who attended these workshops, the data available to quantify this impact was limited, and the impact on producers was considered to be 'fairly low'. Beyond those producers directly involved in the pilot, as far as the authors are aware, none of the recommendations from the project have been implemented at an industry level, other than an ongoing focus on commercialisation of the AWI Smart Tags, which was already underway independently of this project.
Thus, for the purpose of the current impact assessment, it has been concluded that this project has had very minimal impact on a very small number of producers which has been unable to be quantified due to a lack of appropriate evaluation data to assess.

9.1.15.2 Merino Reproduction Efficiency, Fitness and Survival

The primary aim of this project was to provide a comprehensive dataset on reproduction and lamb survival from scanning through to yearling age for the New England Merino Lifetime Productivity (NE MLP) Project flock to add to industry knowledge about the factors influencing lamb survival. The specific project objectives were:

1. To better quantify the genetic and environmental contributions to reproductive performance of Merinos, in utero loss; neonatal mortality; and survival to marking, weaning and yearling ages.

2. To investigate the extent to which fitness of neonatal lambs affects their later age fitness, productivity and survival.

The intended project outcomes were to:

- Add precision to genetic parameter estimates for existing reproduction traits of Merinos, and to be a valuable additional data source and genetic link for reproduction records in MERINOSELECT.
- Enhance understanding of areas/time of loss and lamb wastage as a result of ewe reproductive performance and lamb survival data collected and analysed.
- Improve economic evaluation of the impact of genetic contribution to net reproduction rate by comparison of sire or sire type performances.
- Enable fitness traits and morbidity data in the neonatal stage to be collected and thereafter evaluated in relation to fitness and survival to yearling age.

As would be expected, the study found that dystocia and starvation were the major causes of neonatal lamb mortality, and from conception to yearling age, neonatal mortality was overwhelmingly the largest contributor to mortality up to yearling age (Smith, 2020). Based on the evidence in the form of between-sire variation reported, both dystocia, and to a lesser degree starvation, were found to have a genetic component. However, the author reported that the neonatal mortality traits examined tended not to lend themselves well to direct selection as they have low heritability and low variance. It was noted that further research is required into methods to aid genetic improvement in dystocia rates to improve lamb survival in Australia (Smith, 2020). Although it was found that there may also be a genetic component to propensity for mortality associated with starvation, the author suggested that exposure and mismothering can perhaps be better addressed through attention to producer education and on-farm adoption of lambing ewe management practices.

Extension of the findings from this project to producers will involve development of a fact sheet, articles in Beyond the Bale and other relevant AWI publications/online articles and presentations at the 2019 and 2020 MLP field days. The key extension messages include (J. Smith, CSIRO, pers. comm.):

- Neonatal lamb survival and fitness have a genetic component so improvement in lamb survival and fitness can come partly from genetic improvement and partly from improved management.
- Dystocia and starvation/mismothering account for approximately 80% of neonatal mortality and both are associated with birth weight (but in opposite ways).
- Birth weight (and hence attention to birth weight ASBVs in Sheep Genetics) is part of the answer.
- Neonatal fitness is associated with fitness to yearling age, so if you can keep them alive and well early on, there is a better chance of survival and productivity later on.
- Fitness to yearling age has positive genetic correlation with certain production traits (FAT, EMD, SL) so selection of sires that are superior for those traits may help improve fitness (but there is only preliminary evidence for this so far).

Much of this extension messaging is around information sharing and generating awareness rather than advocating for any particular practice changes that have been shown to measurably increase ewe reproduction rate. It was also noted by the researcher that many of these messages are not new. On this basis, and given the limited and primarily one-way extension of project findings, for the current impact assessment it has been concluded that there has only been potentially minor impact, and no

measurable impact, in terms of management practice changes at the farm level that could be attributed to this project.

However, the research has contributed new knowledge toward potential future Merino selection indices that either focus strongly on a low maintenance/easy care breeding objective, or equally accommodate aspects of production and cost-of-production for a more balanced breeding objective. It was also suggested by the researcher that the data collected and analysed for this project would contribute to increasing the accuracy of existing sheep reproduction traits. The NE MLP reproduction records only involves limited data to date, which is expected to be available for inclusion in MERINOSELECT later in 2020, with additional data becoming available in future years (J. Smith, CSIRO, pers. comm.). It is estimated that addition of this data will generate only a small increase in breeding value accuracy, estimated at between 1 and 2% (A. Swan (AGBU) and J. Smith (CSIRO) pers. comm.).

9.1.15.3 More Lambs per Ewe Lifetime Through Better Genetic Evaluation Systems

This project targeted more comprehensive recording of pedigreed ewes joined to lamb as yearlings, and obtained data from 9 breeders in three states (NSW, VIC and SA), some with multiple breeds within location, totalling 12 industry flocks representing maternal, terminal and Merino breed types. The focus ewes (n=3,296) were born in 2012, and a large proportion of these ewes were joined to first lamb as 1-year olds in 2013. In addition to recording reproductive outcomes, additional data was collected on either post-weaning or pre-joining condition score (n=1,322+1,423), pre-joining weight (n=3,098) and progesterone (n=1,890) early in the joining period to more closely examine the associations between pre-joining weight and condition score with hormonal status and the observed reproductive outcomes. Progesterone concentrations were measured on all ewes within a contemporary group at day 14 after ram/teaser introduction, and this was used as an indirect measure for identifying the physiological attainment of puberty.

The research found that fertility of ewes joined to lamb as yearlings varied widely between flocks, as has been observed previously, ranging from 0% (Superfine Merino flock) to 75% (Terminal composite flock) (Bunter and Newton, 2014). Several key factors were identified which were significantly associated with reproductive outcomes for ewes joined to lamb as yearlings. These included contemporary group and ewe genotype within flock, age of ewe at first exposure to rams for joining, and age class of their dams.

Progesterone concentrations were lowly correlated with weight and uncorrelated with condition score genetically, while weight and condition score were strongly correlated genetically with each other. Therefore, the attainment of puberty (as indicated by progesterone concentrations) was found not to be controlled by exactly the same genes that influence pre-joining weight or condition score, and breeders therefore cannot rely solely on pre-joining weight to be an accurate indicator of sexual maturity in their ewe lambs. Based on results from this study, some observations were made by the researchers (Bunter and Newton, 2014):

- Pre-joining weight, condition score and progesterone each explain relatively little, phenotypically, of the variation between ewes in reproductive performance within contemporary groups.
- In the absence of very high estimates for genetic correlations between traits, it is important to record reproductive performance directly for genetic evaluation purposes and to not rely solely

on data from other traits, because accuracy of breeding values for reproductive traits will be low where only correlated data are available.

- The current recommendations to improve the reliability of lambing performance of yearling ewes are largely based on obtaining a minimum weight at joining. These recommendations should be expanded to include assessment of condition, which is relatively easily scored on farm.

- Since progesterone measured from a single field sample was moderately heritable and associated with fertility and reproductive outcomes, both across and within flocks, the method used in this study is considered adequate for evaluating differences between sires in the progesterone levels of their daughters measured early in the joining period. However, the usefulness of this information for genetic evaluation of yearling reproductive performance needs to be evaluated further by obtaining more accurate estimates of genetic correlations.

- Because of the relatively low number of records, resulting in large standard errors for parameter estimates, more data are required to obtain accurate estimates of genetic correlations between pre-joining weight or condition score and progesterone with reproductive outcomes.

- Significant service sire effects were evident for fertility and the composite traits NLB and NLW. Choice of service sires (age, experience), use of syndicates, and joining paddock characteristics might have a bigger impact on yearling reproductive performance compared to adult ewes and requires further investigation.

- Based on limited data from 1 flock only, the efficacy of pharmaceutical intervention could be investigated experimentally for improving commercial flock outcomes. However, this strategy would not seem sensible for selection purposes since it will almost certainly mask early natural early attainment of puberty.

- Extension and pipeline development have only been partially successful. However, MLA are able to promote the use of existing “repro ready” software to improve the quality of reproductive data entering Sheep Genetics analyses.

According to the researcher (K. Bunter, AGBU, pers. comm.) this project contributed towards the ability to produce more accurate ASBVs for maternal breed yearling ewe reproductive performance through Sheep Genetics, and demonstrated that age at joining, pre-joining weight, condition score and the attainment of puberty are all important for successful joining of ewes to lamb as yearlings. This contribution has been achieved in combination with other projects undertaken at AGBU over the ensuing years by:

- Assisting to define all reproduction component traits (conception, litter size, rearing ability) separately for yearling and adult ewes;
- Fitting better models to these traits;
- Including additional traits which were poorly represented at the time (e.g. ewe condition score pre-joining) to provide correlated information; and
- Assisting to encourage breeders to improve their data recording.

According to K. Bunter (pers. comm.), breeders are beginning to better understand the importance of recording reproduction accurately to enable more accurate decision making to improve reproduction for cumulative gains, independent of selecting bigger ewes.

9.1.15.4 Sheep CRC

The Sheep CRC was established in 2001 to integrate wool and meat R&D with the focus on understanding what the consumer wanted from the sheep industry in order to develop the technologies and know-how required to meet and exceed these expectations. The program involved a collaboration with commercial breeders, sheep producers, processors and retailers working with research organisations, universities, R&D corporations and private sector consultants and advisors. The final phase of the Sheep CRC focused on three programs of work:

- Enhanced sheep wellbeing and productivity: focused on the development of software and online applications to improve wellbeing and productivity.
- Quality-based sheep meat value chains: focused on improving carcase value based on lean meat yield and eating quality.
- Faster affordable genetic gain: focused on the development of new and improved breeding values and genetic tools.

Program 3, 'Faster affordable genetic gain', involved delivery of two key projects which included research and activities to improve sheep reproduction outcomes:

- Using full genome sequence information to accelerate genetic gain: This project focused on the continual development of a low-density SNP chip for genomic predictions and improved techniques for imputing to higher densities resulting in greater breeding value accuracy. The project also contributed to the development of single step predictions for sheep and incorporation of this information into LAMBPLAN and MERINOSELECT.

- Breeding program design and industry training: This project focused on developing new breeding program designs and software applications that exploit the use of genomic information to facilitate faster genetic gain. It involved use of optimal flock structures, the numbers of animals to genotype, which animals to get higher sequence information on and which animals require phenotype information collected. Delivery of the project involved close collaboration with breeders and consultants to ensure a high level of engagement and interaction through knowledge transfer and feedback such that breeders have access to the best available knowledge for decision making.

These projects delivered the following sheep reproduction related outcomes to industry (Sheep CRC, 2019):

- Improved genetic tools;
- An improved genetic marker panel which is expected to increase the predictive accuracy of genetic analysis and increase the rate of genetic gain;
- The scope of the genomic Flock Profile test has been expanded with the addition of information related to reproductive efficiency. This has increased value for producers to better manage poor reproductive efficiency;

- Increased adoption of genomic testing by producers. This has resulted in accelerated rates of genetic gain through more precise selection of the genetics required to improve flock performance for productive traits and environmental conditions.
- Development of a new 50k SNP test that incorporates around 2,500 predictive SNPs identified through analysis of full-sequence DNA data. The new test is expected to increase the accuracy of genomic prediction for reproduction traits without increasing the cost of testing.
- Education and training for postgraduate students; Communication and training activities to promote project outputs, reducing the time from research to utilisation by industry; and Development and hosting of computer apps to assist producers and breeders with their management decisions.

9.1.15.5 Advanced Genetic Evaluation Tools and Systems Enabling Faster and More Valuable Genetic Gain in the Red Meat Industries

This project aims to significantly enhance the genetic evaluation tools and systems used in Sheep Genetics, to more fully utilise genomic information, to develop improved methods of handling high frequency longitudinal data, to allow inclusion of new traits for selection, to facilitate storage and utilisation of data, to facilitate diagnosis of performance recording issues and the effectiveness of breeding program implementation, and to deliver high-level training and mentoring in diagnosis of and recommendations for breeding programs (Jeyaruban *et al*., 2019). Together, these outcomes will provide the basis for faster rates of genetic progress in sheep, and underpin planned integrated technology transfer activities.

The main technical developments from this project include: next generation analytical software (OVIS 4.0) to seamlessly combine pedigree, performance and genomic data, more efficient computing strategies which will provide the basis for continual evaluation, improved breeding objectives, new traits for sustainable production of higher quality products, and better methodology to optimise breeding program design. The project aims to ensure that sheep seedstock breeders have access to the best tools possible for genetic evaluation, and that Sheep Genetics can provide accurate and useful information to breeders, commercial producers and other sectors of red meat value chains.

Project objectives include:

- Computation of Estimated Breeding Values in the era of genomics and big data – faster and more frequent analyses, with more data included
- Productivity gains through new on- and off-farm traits
- Maximising genetic gain

This project is currently in progress and is expected to be completed by September 2021. In terms of sheep reproduction outcomes, the following areas of expected impact from this project include:

- Improved reproduction trait ASBV & RBV accuracy (inclusion of MLP lifetime data in MERINOSELECT/updated accuracy algorithm/improved analysis models/additional data via the mating module/additional management grouping for reproduction analysis);
- New maternal yearling and adult reproduction RBVs - conception (con), litter size (ls), ewe rearing ability (era);
- Dohne Merino reproduction trait analysis;
- Use of pregnancy scanning data to inform reproduction analyses;

- Improved lambing ease and gestation length breeding values;
- Additional correlated traits (joining weight and CS and maternal behaviour score); and
- Increased adoption of reproduction RBVs and ASBVs by both studs and commercial producers.

9.2 Summary of Product Impact Assessment Metrics

Table 20 provides the overall investment criteria results for sheep reproduction RD&E investment in Category 1 projects[3] during the review period over 15, 20 and 25-year time horizons utilising a 5% discount rate. Over a 25-year time horizon, the economic assessment returned a net present value to industry of $93.40 million with a benefit cost ratio of 5.2 and an internal rate of return of 39%. Return on MLA and AWI investment has been provided separately from returns on total investment, which also includes industry in-kind and cash co-investments for some projects.

Table 20: Investment criteria results for Category 1 sheep reproduction project investment (5% discount rate)

Investment Return	NPV	B:C Ratio	IRR
15 Years			
Total Investment	$52.11 M	3.3	37%
MLA Investment	$11.23 M	2.4	25%
AWI Investment	$37.10 M	4.5	52%
20 Years			
Total Investment	$76.07 M	4.4	38%
MLA Investment	$18.91 M	3.4	27%
AWI Investment	$49.81 M	5.7	53%
25 Years			
Total Investment	$93.40 M	5.2	39%
MLA Investment	$25.20 M	4.2	28%
AWI Investment	$57.93 M	6.5	53%

A sensitivity analysis was undertaken to assess the impact of a +/- 20% variation in both the increase in number of lambs weaned and the net value per additional lamb weaned on investment criteria results (Table 21). The sensitivity analysis was performed using a 5% discount rate for total investment over a 25-year time horizon. All other variables remained at their base scenario values.

Table 21: Sensitivity analysis of investment criteria results for Category 1 sheep reproduction project investment

Investment Criteria	High Scenario (+20% productivity gain and net lamb value)	Base Scenario	Low Scenario (-20% productivity gain and net lamb value)
NPV	$197.84 M	$93.40 M	$19.21 M
B:C Ratio	9.9	5.2	1.9
IRR	68%	39%	13%

With a 20% higher rate of productivity gain and a 20% higher net lamb value, total RD&E investment returned a NPV of $197.84 million with a B:C ratio of 9.9, and with a 20% lower rate of productivity gain and a 20% lower net lamb value, the NPV was $19.21 million with a B:C ratio of 1.9.

[3] The project created or contributed to an existing or new output (product) with directly attributable adoption outcomes and adoption related productivity impacts.

Finding 26: *The overall economic assessment of all projects in Category 1 (the project created or contributed to an existing or new output (product) with directly attributable adoption outcomes and adoption related productivity impacts) returned a net present value to industry of $93.40 million with a benefit: cost ratio of 5.2 and an internal rate of return of 39%. With a 20% higher rate of productivity gain and a 20% higher value of additional lambs weaned, RD&E investment returned a NPV of $197.84 million with a B:C ratio of 9.9, and with a 20% lower rate of productivity gain and a 20% lower value of additional lambs weaned, the NPV was $19.21 million with a B:C ratio of 1.9.*

The results of the economic impact assessment for each product are provided in Table 22.

Table 22: Key impact assessment results by product

Product	Product Category	Annual net benefit ($ per ewe undiscounted by time)	Adoption start and peak year and peak number of ewes impacted	Investment criteria results
Flushing ewes to increase conception and fecundity	Conception and Early Embryo Mortality	None	N/A	PV Costs: $1.03 M
Fertility of sexed ram semen	Conception and Early Embryo Mortality	None	N/A	PV Costs: $0.23 M
Metabolic disorders in pregnant and lambing ewes	Ewe Nutrition (Diet/Supplements)	None	N/A	PV Costs: $0.80 M
Improving lamb survival through lambing density and mob size	Lamb Survival (Management)	$1.59	Start: 2016/17 Peak: 2019/20 Ewes at Peak: 0.11 M	PV Benefits: $2.03 M PV Costs: $1.85 M NPV: $0.18 M B:C ratio: 1.1 IRR: 6%
Foetal aging for increased lamb survival	Lamb Survival (Management)	None	N/A	PV Costs: $0.22 M
Merinos to Market/Realising Performance Potential	Adoption	$0.96	Start: 2016/17 Peak: 2019/20 Ewes at Peak: 0.13 M	PV Benefits: $1.49 M PV Costs: $0.51 M NPV: $0.98 M B:C ratio: 2.9 IRR: 23%
It's Ewe Time	Adoption	$0.48	Start: 2018/19 Peak: 2021/22 Ewes at Peak: 0.66 M	PV Benefits: $3.64 M PV Costs: $0.63 M NPV: $3.01 M B:C ratio: 5.8 IRR: 54%
Lifetime Ewe Management	Adoption	$0.66	Start: 2014/15 Peak: 2020/21 Ewes at Peak: 5.31 M	PV Benefits: $45.90 M PV Costs: $5.41 M NPV: $40.92 M B:C ratio: 8.5 IRR: 72%
PGS – Lifting Lamb Survival	Adoption	$1.13	Start: 2017/18 Peak: 2019/20 Ewes at Peak: 0.18 M	PV Benefits: $2.41 M PV Costs: $0.89 M NPV: $1.52 M B:C ratio: 2.7 IRR: 26%

Product	Product Category	Annual net benefit ($ per ewe undiscounted by time)	Adoption start and peak year and peak number of ewes impacted	Investment criteria results
Bredwell Fedwell	Adoption	$0.53	Start: 2013/14 Peak: 2018/19 Ewes at Peak: 1.58 M	PV Benefits: $12.11 M PV Costs: $1.45 M NPV: $10.66 M B:C ratio: 8.3 IRR: 68%
RAMping Up Repro	Adoption	$0.99	Start: 2017/8 Peak: 2020/21 Ewes at Peak: 1.05 M	PV Benefits: $10.92 M PV Costs: $0.10 M NPV: $10.82 M B:C ratio: 112.5 IRR: N/A
Making More from Sheep – Reproduction only	Adoption	$0.99	Start: 2013/14 Peak: 2017/18 Ewes at Peak: 0.90 M	PV Benefits: $12.17 M PV Costs: $2.33 M NPV: $9.84 M B:C ratio: 5.2 IRR: 33%
Measuring behaviour to improve maternal ability (PDS)	Adoption	None	N/A	PV Costs: $0.04 M
Shelter options for increased lamb survival (PDS)	Adoption	$1.20	Start: 2015/16 Peak: 2019/20 Ewes at Peak: 0.01 M	PV Benefits: $0.16 M PV Costs: $1.19 M NPV: -$1.03 M B:C ratio: 0.1 IRR: N/A
Temporary fencing for improved lamb survival (PDS)	Adoption	$3.91	Start: 2017/18 Peak: 2020/21 Ewes at Peak: 0.01 M	PV Benefits: $0.55 M PV Costs: $0.22 M NPV: $0.33 M B:C ratio: 2.5 IRR: 21%
Nutritional manipulation of sex ratio (PDS)	Adoption	None	N/A	PV Costs: $0.12 M
Chaff carts as sheep management tools (PDS)	Adoption	$3.11	Start: 2017/18 Peak: 2020/21 Ewes at Peak: 0.43 M	PV Benefits: $14.08 M PV Costs: $0.08 M NPV: $13.99 M B:C ratio: 173.6 IRR: 253%
Good clover, bad clover (PDS)	Adoption	$1.04	Start: 2017/18 Peak: 2020/21 Ewes at Peak: 0.08 M	PV Benefits: $0.94 M PV Costs: $0.12 M NPV: $0.83 M B:C ratio: 8.2 IRR: 53%
All PDS projects	Adoption	$2.78	Start: 2015/16 Peak: 2020/21 Ewes at Peak: 0.54 M	PV Benefits: $15.72 M PV Costs: $1.77 M NPV: $13.95 M B:C ratio: 8.9 IRR: 31%
Sensor technology for establishment of maternal pedigree	Applications for Sensor Technology	None	N/A	PV Costs: $0.86 M

Product	Product Category	Annual net benefit ($ per ewe undiscounted by time)	Adoption start and peak year and peak number of ewes impacted	Investment criteria results
Genetic gains in ewe reproduction rate	Genetics	N/A	Start: 2015/16 Peak: 2036/37 Ewes at Peak: 4.24 M	PV Benefits: $9.26 M PV Costs: $4.18 M NPV: $5.08 M B:C ratio: 2.2 IRR: 12%

9.3 Uncertainties and Limitations

There are various uncertainties and limitations associated with both the estimates of impact and adoption for the products evaluated during this impact assessment. The following range of uncertainties and limitations have been identified:

- Uncertainty regarding the transfer of experimental and trial results to producer impacts on farm.
- Uncertainty regarding the actual level of producer adoption occurring relative to producer stated intentions to adopt.
- Uncertainty regarding the degree to which producer survey results are likely to represent the target population.
- Uncertainty regarding the accuracy of producer self-reported impacts at a single point in time in representing actual long-term average impacts.
- Uncertainty regarding future producer capacity to continue receiving expected benefits due to unknown seasonal/climate change impacts and personal situations e.g. retirement, selling the business, enterprise changes.
- Uncertainty regarding the level of dis-adoption of various practice changes 1-2 years after initial adoption.
- Limitations associated with making estimates of impact/adoption where little empirical and/or intent to adopt data exists.
- Limitations associated with making estimates of the sheep reproduction proportion of total investment in some products where the specific allocation of investment to sheep reproduction was undefined.
- Limitations associated with accurate quantification of in-kind co-investment for some products.
- Limitations associated with duplication of business impacts where multiple entries from the same business have been recorded in participant evaluation data as making or intending to make the same practice changes.

Efforts have been made to address key limitations and areas of uncertainty wherever possible, and a conservative approach has been taken to making estimates of both impact and adoption. In situations where no data was available to provide a reasonable estimate of impact, the product was removed from the impact assessment and will be assessed in future when more accurate data becomes available. In some cases, research and extension activities are ongoing and new data will become available in the future to update current estimates of impact and adoption.

10.0 Key Gaps in Sheep Reproduction RD&E

This section presents the findings of the review in terms of current gaps in sheep reproduction R&D and in extension and adoption, and provides a series of recommendations for addressing these gaps.

10.1 Sheep Reproduction R & D Gaps

Figure 29 provides a summary of the key R&D gaps identified by stakeholders during the review process. The stakeholder feedback represented a spectrum of opinions and ideas that come with all of the acknowledged bias of people who work in particular areas of expertise. Some stakeholders were across a lot of issues and projects, while others were only fully aware of activities in their own area of expertise, thus their opinions were framed by that bias. It should also be noted that not all stakeholder opinion was factually correct, thus footnotes have been included to correct mis-information or to identify work currently under development.

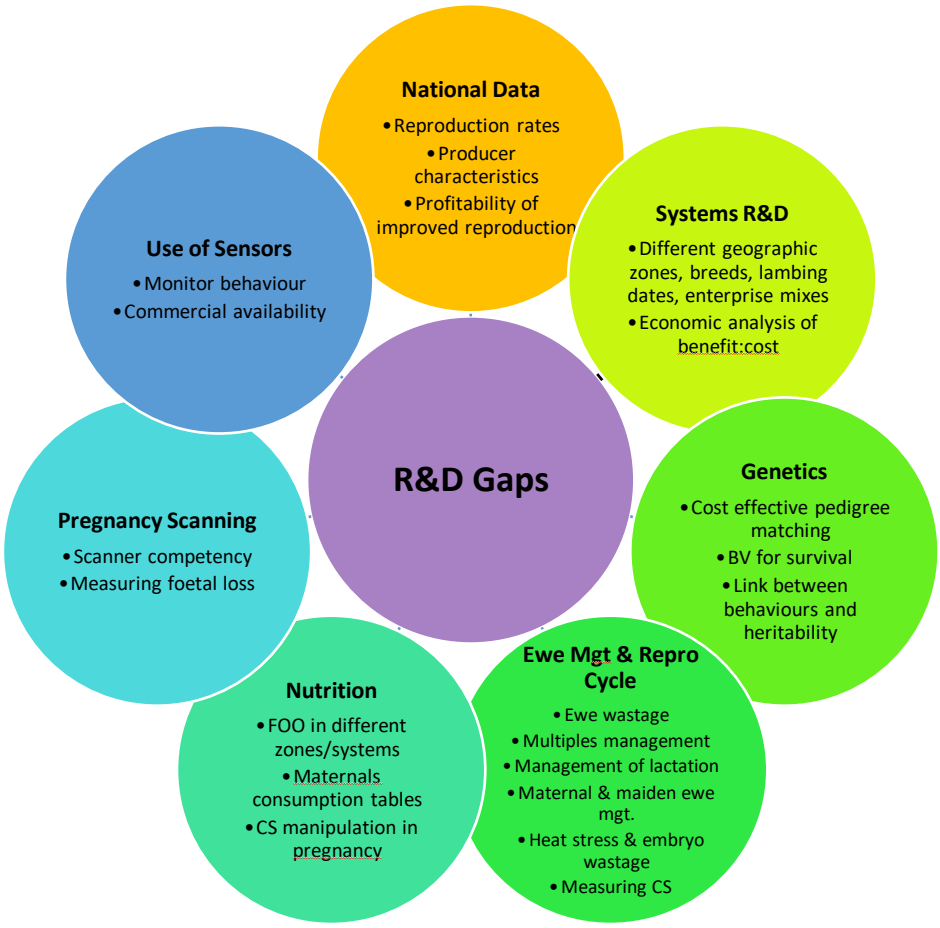


Figure 29: Key sheep reproduction R&D gaps identified by stakeholders

A summary of the key issues raised by stakeholders for each of the key areas identified in Figure 29 is provided below.

1. National Data

Stakeholders identified that there is a lack of accurate time series data available for the following purposes:

- Reproduction efficiency: Data to accurately assess changes in key elements of reproduction efficiency including conception rate, scanning percentage, early embryo loss and lamb survival. It was noted that there are no reliable, repeatable estimates to base progress on or to identify where (regionally, breed and system) the issues really are to inform R&D investments.

- Characteristics of producers: A lack of sufficient data regarding what type of producers are attending which events/programs, how many are actually adopting and sustaining that adoption, what are they adopting, what are they likely to adopt, and what are the characteristics of those that adopt. It was noted that this type of information could be utilised to better target extension e.g. Should we be targeting the top producers, the bottom? Where is the best 'bang for our buck'?

- Profitability of improved reproduction: Stakeholders identified that there is no nationally accepted way of demonstrating if a change in reproduction is going to be profitable. It was noted that there is a lot of here-say regarding what practices are profitable, but not a lot of evidence across a range of environments and systems for different types of practice changes.

2. Systems R&D

A frequently reported gap in sheep reproduction R&D was a lack of context for application and implementation of R&D outcomes in farming systems:

- What are the differences in recommendations for different geographical zones, breed types, lambing dates and enterprise mixes? Current recommendations are not sufficiently specific.
- Profitability versus productivity gains for different zones, breeds, enterprise mixes, scale and lambing dates.
- Economic value of specific management practices in different zones, breeds, enterprise mixes, scale and lambing dates e.g. value of scanning and condition scoring in a number of different scenarios, value of collecting data on maternal performance etc.

3. Genetics

Stakeholder feedback regarding R&D gaps in sheep reproduction genetics included:

- Need for a breeding value for lamb survival (not just NLW)[4].
- Need for greater understanding of the link between maternal behaviours and heritability[5].
- Need for access to cost effective maternal pedigree matching technology for producers.
- Need for greater understanding of the link between genetics and animal behaviour e.g. to what extent is animal behaviour genetically determined such as mating behaviour in rams, and maternal behaviours in ewes.
- Better meat Merino ewes – what to select for[6].

[4] Sheep Genetics are aiming to increase survival and welfare traits in the indexes. Have ewe rearing ability now. MLP will be able to address a lot of the reproduction traits and their relationship with production and survival traits – holistic sheep profitability picture. AGBU has a priority to improve reproduction breeding values – collection and analysis – and looking to implement data quality index to improve the quality of data recorded on-farm.

[5] A report is due to be published by Adelaide University that addresses this and Sheep Genetics has a report on Maternal Behaviour and Lambing Ease, so heritability is known.

[6] It could be argued that we know how to do this already but have not succeeded yet.

- Need for greater understanding of the value of selecting for muscle and fat to increase lamb survival[7].

4. Ewe management and the reproduction cycle[8]

A range of R&D gaps relating to specific elements of the reproduction cycle and ewe management were identified by stakeholders:

- Conception:
  - How to compensate for heat stress effects[9].
  - Causes of embryo wastage and how to measure and prevent[10].
- Ewe wastage:
  - How can it be prevented practically (not just theoretically) with case studies to demonstrate how producers have improved it cost and time effectively.

- Management of twins/triplets:
  - How best to supplementary feed at lambing to reduce mismothering/disturbance.
  - Impact of a range of shelter types, including costs and benefits of lambing in sheds.
  - Containment feeding during pregnancy – impacts economically and practically.
  - Understanding why dystocia and mismothering occur and how to prevent or select against it.

- Management of maternal ewes:
  - How to take weight off during pregnancy without compromising lamb survival.

- Lactation:
  - Applying other mammalian knowledge of lactation to sheep to improve lamb survival and lamb growth rates.

- Maiden ewe management:
  - Conception differences in maidens compared to older ewes – are differences preventable? Can the same conception be achieved in maidens compared with older ewes? Thought to be more factors than nutrition and hitting key critical weights involved.
  - Possible role of campylobacter vaccine in negatively impacting conception and early embryo losses in maiden ewes.
  - Maiden Merino performance – how to improve.

- Condition scoring:
  - How to increase the accuracy and practicality of condition scoring as a regular on-farm management tool. The need for an automated objective means of measuring CS on farms[11].

[7] AWI's Merino Lifetime Productivity is proposing to investigate the variability observed in using these ASBVs for selecting for reproduction.
[8] AWI's Merino Lifetime Productivity is proposing to address a lot of the reproduction traits and their relationship with production and survival traits – holistic sheep profitability picture.
[9] MLA is currently funding a project on heat stress impacts.
[10] Perception exists that this is low but no evidence or data could be found during this review that supports this perception.
[11] Research is currently underway into technology to automate the process of condition scoring.

5. Nutrition

Many stakeholders commented on difficulties associated with accurate assessment of FOO and gaps in understanding of how to practically manipulate nutrition to increase sheep reproduction outcomes:

- Estimating FOO in different geographical zones, pasture types and times of the year. No good tools exist for remote sensing or for dry feed (FOO galleries insufficient for dry feed, stubbles, and different pasture types)[12]. There is a need for practical tools for estimating FOO i.e. pastures from space.
- Understanding of when consumption figures change, especially in Maternals[13] that do better than LTEM guidelines suggest they should. Need feed tables for Maternals in LTEM.
- How to manipulate condition score practically, especially reducing condition during pregnancy without impacting on lamb and ewe survival. LTEM has the principles on how but not the stories of how it happened and what the pitfalls are.

6. Pregnancy scanning

A number of stakeholders identified a need for a standard set of competency requirements for scanners to minimise a lack of scanner competency[14] as a deterrent for adoption of scanning. It was also noted that there is a gap in the usage of pregnancy scanning to measure rates of foetal loss.

7. AI in sheep[15]

In light of a general reduction in the success rates for AI in recent years, some stakeholders identified a need for improved AI techniques and understanding of how they can be used to better affect.

8. Use of sensors

Some stakeholders identified a need for greater use of sensor technology as research and commercial tools to monitor animal behaviour in addition to use for establishment of maternal pedigree, reproductive behaviours, and animal movements in paddocks etc[16].

Overview

It was the general view of stakeholders that sufficient research has been undertaken to provide answers for a large number of sheep reproduction issues, however the knowledge needs to be applied in different systems and zones to determine what works in which environments and systems. Stakeholders also reported that there is research that has not been fully reported that needs to be assessed in a systems context to determine what is adoptable. Many stakeholders felt that the immediate future focus should be on driving adoption of what is already known, however also noting the importance of maintaining R&D capacity and capability by continuing to fund blue sky type research with the potential to generate significant change on farms.

[12] AWI has an on-going project to expand FOO galleries and understanding of FOO in different climates/times of the year.
[13] MLA has the research and it is being translated into tables for LTEM.
[14] There is a project currently underway funded by AWI that may address this issue.
[15] SARDI and Sydney University have multiple projects underway involving AI that will address some of the issues.
[16] There are multiple projects underway involving sensors – not enough results to report yet.

Finding 27: *It was the general view of stakeholders that research to date has provided answers to a large number of sheep reproduction issues, however that knowledge has not been well applied and adapted to different systems and zones to facilitate broad industry adoption.*

Some stakeholders also commented on the project funding model in that it is skewed too much to what SALRC/WALRC identifies as being important without sufficient consideration in accounting for 'what they don't know', and that priorities change too quickly, round by round, and a longer term approach to sheep reproduction R&D investment is needed. It was also noted by some stakeholders that consultants who work directly with producer clients are an underutilised resource in the R&D process and that there is an opportunity to increase their involvement in the generation of research ideas, 'ground truthing' research ideas and in modifying and adapting adoption products and extension messages for more successful and broader industry application.

Finding 28: *Feedback from some stakeholders suggested that the project funding model is overly reliant on priorities identified by SALRC/WALRC without sufficient consideration for 'what they don't know'. It was also considered by many that investment priorities change too quickly, and that a longer-term approach to sheep reproduction R&D is required.*

Finding 29: *Stakeholder feedback suggests that consultants who work directly with producer clients are an underutilised resource in the R&D process and that there is an opportunity to increase their involvement in the generation of research ideas, 'ground truthing' research ideas and in modifying and adapting adoption products and extension messages for more successful and broader industry application.*

In short, it is the view of the authors that the R&D appears to commence with the gaps in knowledge and understanding rather than being data driven i.e. What are the big issues on farm, that if solved, would create widespread change, and what needs to happen to achieve that change? There is a need to work back from the problem to generate a solution rather than investing in what is thought to be the solutions but with no context on how much change they would affect if adopted.

Finding 30: *It appears that R&D into sheep reproduction has been overly focussed on identifying and filling knowledge gaps rather than clearly defining problems at the farm level that need to be solved, and identifying what the best opportunities are for practically (and profitably) solving those issues.*

10.2 Sheep Reproduction Extension and Adoption Gaps

Figure 30 presents a summary of the key extension and adoption gaps identified during the review process.

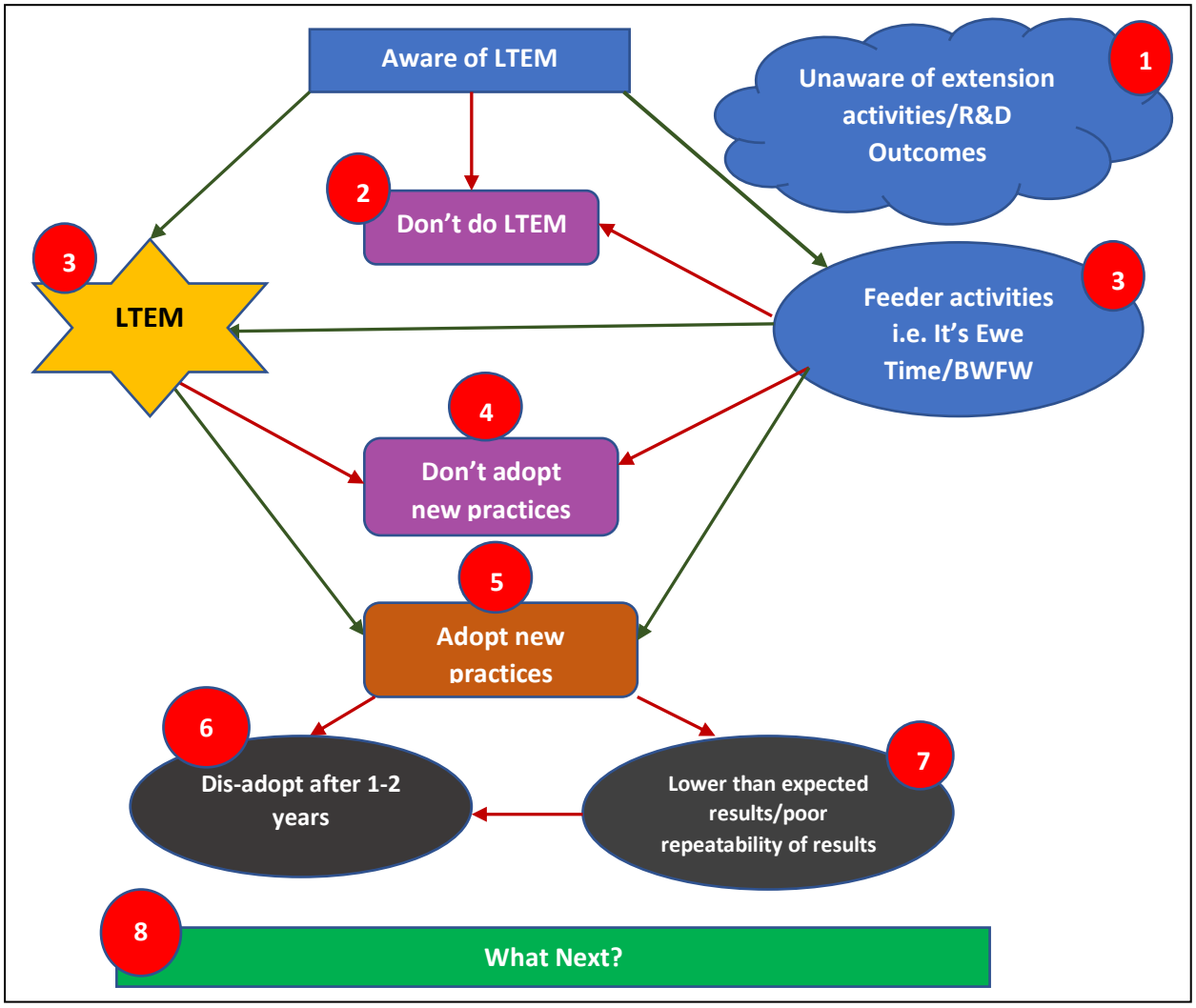


Figure 30: A summary of the key gaps identified for sheep reproduction extension and adoption

1. **Awareness:** Many producers are still unaware of many of the R&D outcomes and of what sheep reproduction extension programs and activities are available.

   There is potential opportunity to identify and utilise high volume points of industry contact to create greater awareness of extension programs. For example, engaging with sheep studs to include advertising of events/programs in ram catalogues. This could be facilitated via service providers such as stock agents, who have a vested interest in increasing sheep reproduction rates. There may also be an opportunity for industry to provide displays at ram/sheep sales to advertise extension activities and programs. It is suggested that most commercial producers, having selected a particular stud from which to purchase rams, have some level of respect for the stud master, thus there may be an opportunity to engage with stud masters as 'influencers'. There are other potential examples of points of contact (e.g. saleyards) and 'influencers' (e.g. product reps, wool brokers), which could be explored.

The review process also identified an opportunity to evaluate sheep reproduction on a regional basis to better target promotional campaigns to local areas. Industry could evaluate ABARES lamb marking rate data on a regional basis to determine which areas have made the least amount of progress in lamb marking rates over the past 5-10 years, and overlay that information with the relative proportion of ewes in those regions to identify high priority locations. An example of this type of analysis has been provided in Appendix G for Victoria. Industry could then engage with local consultants and service providers (e.g. Stock agents/wool brokers) to assess what the local issues and challenges are to assist with identification of the best approach to take in building awareness, and the best approach to take with what management practices to recommend.

2. **Engagement:** Many producers who are aware of LTEM and other extension programs choose not to take part. Why is this and can industry do anything about it? Key issues identified by stakeholders include:

   - High cost of some programs, such as PGS and LTEM, is considered to limit participation[17].

   - Producer reticence in paying relatively large sums of money to participate in extension programs. The sentiment is that producers feel they should not have to pay large fees to access a program that they have already paid for via levies (viewed as 'double dipping'), regardless of whether there is perceived value for money by the producer. It is unknown as to what extent this is limiting participation in the more expensive longer-term programs, such as LTEM.

   - Stakeholders suggested that there is an opportunity to either increase producer subsidies for LTEM, or to decrease the advertised fee for more visual appeal, in an effort to increase participation rates.

   - Identification of any limitations in availability of LTEM and/or other extension activities in some locations, or with the timing of events that may be a limitation to participation, particularly for mixed farm operations. It was noted that most producers are time poor so any strategies which maximise value for the producer while minimising time away from the farm will assist to increase participation in extension activities.
   - Some stakeholders reported that information collected from producers at feeder events, such as It's Ewe Time, regarding producer interest in involvement in other extension activities in their local area, is not always utilised to full effect in facilitating involvement in next step activities for interested producers.

   - Some producers perceive that they do not need to increase reproductive rate. Stakeholder feedback suggests that there appears to be a general lack of awareness among many producers of the level of potential increase in marking rate that could be achieved. Can industry assist to increase awareness of the 'problem' and thereby motivate producers to do something about it by participating in extension programs?

   - There is a general lack of identification of the value proposition for producers in increasing sheep reproduction rate and in the relative value of different approaches for achieving this. Producers need to be able to easily assess the opportunity cost of not making a change and

[17] These programs are heavily subsidised but still require a payment of more than $1,000. Producer investment relates to value proposition. If the producer perceives that the returns to the business from participation in the program will exceed the cost, it is easy to sell the program. If a producer doubts the value, they are less likely to pay the fee.

this opportunity is currently not well incorporated into either promotion of extension programs or within extension programs.

- Some producers do not perceive economic value in the notion of increasing sheep reproduction, particularly with reference to finer self-replacing Merino systems. The origin of this view is often via industry consultants and has been discussed in Section 5 of this report. A process for objective assessment of the value proposition for individual farmers is required.

- MIDAS is the economic tool used by industry to evaluate the profitability of increasing various elements of sheep reproduction. While MIDAS is a valuable tool, it is more appropriate for utilisation in research than it is for extension purposes. It is not transparent and it is not interactive, therefore has limited value in extension to aide producer decision making as to whether or not it is profitable to make particular changes, and also to assess whether these are the best changes to make given other options for expenditure, including debt reduction.

- LTEM has built a strong brand over a long period of time. Is industry leveraging sufficient value from this brand? Are there opportunities to promote the brand more effectively, whether that be via increased use of producer 'champions' or 'influencers' and/or better promotion of success stories (believable success stories) which acknowledge challenges and show how they were addressed, and also how profitable the changes have been over time?

- A lack of sufficient funding to advertise and promote extension programs was identified by stakeholders as a limiting factor in engaging more producers. There was criticism of program co-ordinators who expect the deliverers to do all of the marketing and promotion activities with very little support, including no advertising budget or data on past participants from other events in the area to assist with more efficient targeting of activities to locations and types of producers.

3. **Service Providers:** The capacity and capability of service providers to extend messages is perceived to be variable. In particular, stakeholders commented that:

   - There are some very experienced advisors and deliverers but also some very new consultants without the experience to deliver complex messages. Capability needs to be built.

   - Existing advisors and deliverers reported a lack of sufficient information regarding new adoption messages coming out or that the information involved blanket recommendations without sufficient depth. These next users want better access to the results of R&D and increased opportunities to seek further details. For example, a curated site of reports and information regarding sheep reproduction with author contact details for further follow up.

   - Some stakeholders questioned if there are enough advisors/deliverers in certain parts of Australia, or that many existing deliverers do not see value in undertaking more extension activities (i.e. existing deliverers have reached capacity for LTEM groups in their area so even if extra demand existed, they would not service it, or do not perceive that it is profitable to

deliver more groups[18]). Some areas are not serviced well and some presenters are perceived to be poorly trained/mentored[19].

- Access to experienced/accurate pregnancy scanners is also thought to impact on the pipeline, and although not considered extension deliverers, their role is critical in supporting extension and adoption of practices for improved reproduction outcomes.

4. **Adoption:** There are still producers who choose not to adopt various practices after participating in LTEM and other extension programs. Why is that and can industry do anything about it?

   The main barriers to adoption of recommended sheep reproduction best management practices include:

   - A perceived lack of economic value/inability to determine economic value proposition of change and providing producers with sufficient tools and processes to assess the opportunity cost for their own business of not making a change.

   - Logistics – a lack of sufficient on-farm labour/skills (e.g. for accurate and regular condition scoring) and timing clashes with other management tasks and/or lack of availability of contract labour (e.g. scanners). There was an identified need by stakeholders to better inform producers of what labour-saving technologies are available and to identify ways to implement practices to minimise time and resource requirements which may not represent the 'gold star' approach, but which still create improved outcomes.

   - Lack of required infrastructure/lack of funds to invest. Adoption of LTEM practices appears to be lower in more extensive and mixed cropping systems where there are typically fewer and larger paddocks. Identifying and developing modified best management practices for different operating systems which assist producers to do the best they can within their system and within their financial means is needed.

   - Lack of confidence/motivation to adopt. Stakeholders identified a need for increased support for producers post workshop to implement best practice. If the level of national improvement in lamb survival is less than ideal on animal welfare grounds and/or relative to community expectations, consideration is needed of what opportunity there is for MLA/AWI to invest more in individual farmer coaching/mentoring follow-on services post event/program on the grounds of market failure.

   - A perceived lack of relevance to individual farm systems/or a perceived lack of ability to apply the practices within a system. As noted above, the opportunity to develop additional versions of recommendations which apply to different systems/locations to better target messages that are able to be applied in specific scenarios. Most extension addresses 'what' and 'why' to change, but not always 'how'. Producers need system contextualised information on how to make a change, including benefits and costs, fit for purpose

[18] Presents an opportunity for new deliverers if training and mentoring is provided. Issue has been that new deliverers until recently, were not being trained or mentored to fill these gaps.

[19] It could be argued that it is not the RDCs or industry's responsibility to train experts as it is a 'free market' yet the provision of extension relies on there being 'experts' of a standard to extend the messages. What role do the RDCs and industry play in ensuring 'experts' are extending the right messages or that producers have access equally to these experts to deliver extension regardless of where their farm is located?

technology solutions and an understanding of how to incorporate changes into other enterprises, including effective labour use.

- Lack of support to adopt. Some producers identify as needing support to adopt on their farm to navigate the issues that arise during adoption and to hold them accountable. Follow on programs/groups or one to one support are suggested to keep them on track and help brainstorm issues and approaches to problem solve.

There were only 6 PDSs in the area of sheep reproduction conducted during the five-year SRRIP delivery period (2012-2017). It is well known that providing producers with the opportunity to see how a particular practice works in 'their own backyard' is a very powerful motivator for adoption. Demonstrations on local farms with average producers on a wide scale (i.e. mega PDS) is needed to provide visual proof that changes work in a range of environments and seasons, and how to overcome difficulties with implementation in a localised context. Stakeholders identified that often demonstration farms and case study farms involve producers who are 'high achievers' or perceived to be wealthy rather than 'average' producers with limited resources who are more relatable to the masses.

There may also be an opportunity to establish a national LTEM Farmer Challenge initiative, similar to the MLA Challenge concept. A reasonably large number of farmers could be engaged to participate in the challenge across a range of representative systems and environments. Participants could report regularly on progress and challenges via webinars, social media platforms, presentations at workshops/events, and via newsletter articles/podcasts. The Challenge may also involve an annual field day to facilitate engagement with other local producers. It is suggested that such an initiative would need to run for a reasonable amount of time (5 years) to demonstrate how to manage variables in different seasons and to assess results over a range of seasons. Participants would be supported by a consultant/advisor, and it may be appropriate to provide participants with a small level of remuneration for their time in promoting and extending the results to encourage involvement.

5. **Research to practice:** In many cases R&D outcomes do not translate well to practical extension messages and adoptable changes on farms (research to practice). The identified gaps relate to:

   - Translating results of R&D to highlight new understanding/information and what can be adopted on farm. Lots of R&D results do not lead to a practical application, even though they have generated improved knowledge and understanding.

   - Connecting research outcomes to on-farm practice changes – not all adoptable research messages are converted to on-farm adoption messages which have been field tested for applicability in a variety of scenarios. For example, smaller mob sizes for twins can increase survival by 1-2% but what is the actual recommendation i.e. in what circumstances should producers reduce mob size? Does the recommendation vary depending on what rate of lamb survival is already being achieved? Does it depend on what feed is available or what resources the producer has? Is there any point in reducing mob size if ewes are in poor condition?

6 & 7. **Repeatability of outcomes and dis-adoption**: Stakeholder feedback suggests that there is some level of dis-adoption of best management practices 1 or 2 years after initial adoption due to a combination of less than expected benefits, poor seasons affecting results, poor repeatability

of results across years, and logistical difficulties associated with the time and effort to implement.

Part of the lack of success is suggested to relate to a lack of ability to implement scanning, and part is likely to be due to poor implementation and poor ability to adapt practices across seasons. Difficulties associated with successful implementation of condition scoring as the basis for subsequent ewe management decision making has reportedly resulted in relatively few producers consistently undertaking this practice with successful outcomes. Other issues may include not addressing underlying factors that are limiting the scale of results, for example underlying issues such as disease (listeria/campylobacter/toxoplasmosis), poor animal health (high worm burdens, OJD, lice, liver fluke) or other factors (oestrogenic clovers) impacting on fertility.

This issue of dis-adoption and/or less than potential benefits being achieved could be improved by new technology and provision of additional follow-up support from advisors (via post workshop coaching/mentoring) to assist with problem solving where possible.

8. **Extension Products and Tools:** While it is acknowledged that new/improved extension products are being developed, stakeholder feedback identified the following issues:

   - Lifetime Ewe Management: It is the general view of stakeholders that this program has been successful in generating change in a proportion of participants. In particular it has focused producers on the link between ewe nutrition and conception/survival and encouraged the use of pregnancy scanning. The small group format involving repetition and practice of skills, mostly in the field, with follow up and monitoring of results has generated growth and understanding of principles with practical problem solving in a real farm context.

     However, there are issues identified with the program such as the 'generalised' nature of the notes; difficulty in getting accurate FOO in different scenarios, i.e. crop stubbles, different pasture types; lack of suitably qualified deliverers[20]; lack of sufficient and targeted promotion[21]; and producers dis-adopting condition scoring and measurement of FOO in particular. These issues need to be addressed in order to improve outcomes, but as an extension program, LTEM is viewed as a standout from all of the other extension programs.

     Suggested improvements to the LTEM product include the addition of Maternals[22] and a follow-on/follow-up to check producer progress with implementation of principles after completion of the program. Stakeholders also identified a need for follow on programs from LTEM. Lifting Lamb Survival is one but other models are needed to keep producers progressing and not 'slipping back into old ways' when things become difficult or seasons are less than ideal.

     LTEM has been running since 2006, thus some stakeholders question how producers who have already participated in the program are able to continue to improve reproduction rates

[20] This issue was explored in WA and showed that mentoring was needed to keep new deliverers coming through as others retired. A mentoring system has started but is based on new deliverers self-identifying rather than LTEM actively recruiting new deliverers or advertising for deliverers in different areas.

[21] Promotion of LTEM is word of mouth based on past successes. There have been no active campaign drives to 'recruit' participants in areas or at specific times of the year or in specific regions. This is an approach that may yield an increase in engagement or at least inquiries and could be tested.

[22] This work is in the pipeline for addition into LTEM but is slow being released.

by accessing the latest R&D knowledge. This is possible via participation in events such as It's Ewe Time, Bredwell Fedwell and Picking Performer Ewes, however is there an opportunity to develop a LTEM refresher or update program that is only available to alumni?

Is there also an opportunity to connect LTEM alumni via a social media platform (such as Facebook, Twitter, Instagram, WhatsApp etc) where producers can share progress and problems, receive information about any upcoming events, and engage with industry advisors to seek additional consultancy services. Such a platform could also be utilised by industry to identify key producer 'influencers' that could be engaged to promote relevant extension programs to other producers. The platform may also provide industry with a source of producer case studies and a means for seeking feedback or industry involvement from producers on different issues.

- Stakeholders identified that all extension products, including LTEM, need regionally specific recommendations[23] e.g. localised measures of FOO for cropping/low rainfall zones, and benchmarks need to reflect what is possible in different scenarios/systems/zones. It was also identified that all extension products need to include different sheep breeds and breeding systems (i.e. Merinos and crossbreds and lambing times) as events attract producers running a range of different breed types and lambing times.

- The following comments were made about extension tools:

    - There is a general lack of development of tools from projects such as Passengers to Performers[24]. What new tools are there to assist with decision making on farm around reproduction issues?
    - The demise of pastures from space was mentioned and the difficulty in gaining a good understanding of FOO nationally and how to measure it accurately. This arose frequently as an issue in implementation of accurate feed budgeting and estimation of FOO.

Finding 31: *Stakeholders identified a range of current gaps in sheep reproduction extension in the following key areas:*

- *Producer awareness of R&D outcomes and of available extension programs and activities;*
- *Effective producer engagement to facilitate participation in extension programs and activities;*
- *Capacity and capability of service providers to extend sheep reproduction messages;*
- *Adoption of best practice management strategies for sheep reproduction by producers;*
- *Translation of R&D outcomes to practical extension messages and adoptable changes on farms (research to practice);*
- *Repeatability of best practice management outcomes on farms and producer dis-adoption; and*
- *Extension products and tools.*

[23] Many LTEM trainers made the comment that the FOO recommendations for LTEM were too centred on specialist sheep production areas such as the Western District in Victoria and didn't translate well to areas that were more marginal such as the pastoral and sheep/cropping zones. This remains a gap and estimating feed budgets based on these pasture types is difficult. AWI commented that this is an area being developed currently.

[24] A tool from passengers to performers is under development for the Picking Performer Ewes workshop.

10.3 Addressing Sheep Reproduction RD&E Gaps

The following section provides a series of recommendations to address the key RD&E gaps identified during this review. Specific recommendations for future R&D project investments have not been made as it is recommended that decisions regarding project investments should align with the priorities of an agreed National Sheep Reproduction Plan. It is however, suggested that investment in the future capacity and capability of producers to adapt to climate change and to access and implement new technologies in a practical way will be important priorities for the industry in coming years.

10.3.1 National industry data

A lack of appropriate national time series data to measure improvement in key areas of sheep reproduction efficiency has been identified during this review. Data collected on producer engagement and impact of adoption at the project level was found to be inconsistent, and often incomplete and/or poorly collated. Accurate data on the on-farm or industry impacts of practice change was also difficult to find and relate to profitability. While it was possible to evaluate economic impact for a number of projects, the data gathering and analysis was challenging as most projects had not allowed for follow up with adopters in a way that captured long term whole farm benefits in financial terms.

10.3.1.1 National data collection process

One of the challenges in monitoring the performance of sheep reproduction on farm is the lack of independently reported and validated data that tracks seasonal measures of reproduction, such as conception rates, scanning percentages, lamb marking rates (and hence survival rates), and ewe mortality by region, lambing date, breed and enterprise mix. These are figures that could be collected with changes to the way that ABS/ABARES or MLA/AWI collect and report data. It is suggested that one of these data sources is selected and investment made in adapting it to collect the required data to measure change in all relevant aspects of sheep reproduction efficiency.

10.3.1.2 Establish key metrics for monitoring key performance indicators for the SRRIP

National data is important for high level monitoring of sheep reproduction performance, however at an adoption pathway level a different set of metrics is necessary to measure success. These metrics include engagement, adoption and impact measures so that the success of a suite of projects/programs can be related to the national data to establish how adoption products were used and what impact they had. While this review found that some adoption pathways had adequate metrics and processes, many projects with good outcomes had no adoption pathway for measuring impact and adoption, let alone metrics for evaluation.

10.3.1.3 Monitor and report progress against KPIs of SRRIP

Throughout this review it was evident that the SRRIP had not been reviewed since it was developed and accepted. While MLA/AWI may have tracked national marking rates each year in a general sense, it was evident that this information was not utilised to assess whether the SRRIP and related sheep reproduction investments were achieving objectives. If the SRRIP had been monitored at least annually, continuous improvement could have occurred to ensure priorities for investment were adjusted and adoption pathways established as projects reported adoptable outcomes. Slight

adjustments annually may have kept the plan on track and evolving as other industry priorities changed and the impacts of drought/climate change on sheep reproduction were addressed.

Recommendation 12: *Establish and maintain a national database of key performance indicator data for monitoring changes in sheep reproduction efficiency by:*

- *Investing in the adaption of one national data collection process to enable reporting against all key statistics for tracking progress against sheep reproduction strategic objectives;*
- *Developing a process for ensuring that all extension/adoption pathways establish and monitor key metrics for measuring engagement, adoption and impact that can be related to national data; and*
- *Ensuring that data used for reporting progress feeds into continuous improvement and evaluation processes so that results are informing delivery and investments are adjusted accordingly.*

10.3.2 Target audience for extension/adoption outcomes

Throughout this review it was difficult to identify who the target audience was for the SRRIP. Was it all sheep producers in Australia or certain segments? Did it include next users of outputs, such as vets, consultants, pregnancy scanners, or just the end users (producers)? If it included both, what were the targets for engagement, what were the characteristics of the target audience, where was the evidence that they were engaged, and if not engaged, why not? What were the outcomes of the engagement i.e. was it to create awareness, improve knowledge and skills or achieve adoption? What adoption occurred and what impact did it have? Without all of this information (some did exist for some projects), it made it difficult to assess the success or otherwise of engagement and adoption activities, and whether R&D outcomes were successfully implemented, under what circumstances, by whom and to what affect.

10.3.2.1 Define target audiences and segment into next users and end users

Not all adoptable outputs from R&D are applicable to all sheep producers (end users). Some are better targeted to other audiences who work with or provide services to sheep producers. These audiences can be thought of as 'next users' of the adoptable product. An example is veterinarians performing AI who are the target audience for improvements in AI techniques rather than the sheep producers who ultimately benefit from improved conception or cheaper service. For each adoptable output and during the development of a new project, the target audience needs to be defined, including numbers, geographical spread, and key characteristics/demographics.

10.3.2.2 Determine KPIs for adoption and engagement

Once the target audiences are defined, realistic measures for engagement and adoption need to be established to assist with the design of adoption pathways and extension methodology and to determine the level of project investment required. As investment is often the limiting factor, targets need to be carefully considered and methodologies developed that maximise value.

10.3.2.3 Determine methods for engagement and monitor effectiveness

Each target segment needs to be explored to determine how best to engage with them. This requires understanding of their personal motivations, issues, beliefs, production systems and financial drivers. There is much to be gained from exploring how social media is changing the way people engage on a range of issues, and utilising traditional methods of mass engagement with new, more personalised approaches. Word of mouth may still be the best form of advertising to producers but it is how that is achieved that is changing.

Recommendation 13: *Identify and segment the target audience for each adoption product to:*

- *Define:*
    - *End users e.g. commercial sheep producers, seedstock producers and their key characteristics, such as flock size, breed, enterprise mix and size, lambing time, participant age, geographical location.*
    - *Next users and their key characteristics, e.g.:*
        - ✓ *Consultants/advisors – business, technical etc*
        - ✓ *Trainers/educators*
        - ✓ *Extension experts*
        - ✓ *Service providers e.g. stock agents, wool brokers, pregnancy scanners, contractors (shearers, contract marking teams etc), vets, product company representatives, rural financial counsellors, bankers/loan brokers.*
        - ✓ *Researchers*
        - ✓ *Other members of the value chain e.g. wool processors, meat processors*
- *Determine which segments are the target for each extension/adoption message/product and define:*
    - *Engagement targets*
    - *Adoption targets*
- *Determine how best to engage each target audience and how that engagement will be monitored and evaluated.*

10.3.3 Research, development and extension outcomes

This review found that there were a number of notable R&D achievements, but that awareness of outcomes from RD&E projects was variable amongst next users and end users. Even prominent industry experts were unaware of the full range of RD&E currently being undertaken, or had been completed in the last seven years, and many of the producers surveyed could not identify RD&E projects/outcomes in the area of sheep reproduction. While not all R&D projects led to adoptable outcomes, many that had, had not fully developed the adoptable product or the pathway to adoption. Sometimes this was due to a lack of resources to fund the next phase, sometimes it was because adoptable outputs were not a specification of the original project contract, and sometimes the adoptable outputs were limited in their ability to be extended as they had not been designed to cover the range of environments, seasons and situations to suit a broad range of producers.

Many stakeholders interviewed also expressed a view that: *'the RDCs could take the outcomes from the last 5 years of research and develop a whole extension program for the next 5 years without any more research'*. The underlying message was that while investing in more research is still an important priority for solving evolving on farm issues (especially related to adaptation to climate change and social licence to operate), that a greater proportion of available funding needs to be spent on developing, extending and applying existing research outcomes to a broader range of production systems and locations. This includes making the outcomes available to all users, and keeping next users, not just end users, informed of R&D outcomes.

10.3.3.1 Curated database of RD&E reports and information relating sheep reproduction

Stakeholder feedback indicates two main issues with understanding the breadth of RD&E that exists:

1. Lack of general awareness of what is happening in the field of sheep reproduction RD&E such as new projects underway, results of completed work, and new extension programs.
2. Lack of timely access to detailed information from completed RD&E that enables appropriate utilisation (and adaptation if required) of the outcomes directly with individual producers and producer groups.

In compiling the projects for this review, it was obvious that there is no curated database of all projects related to sheep reproduction where all information can be easily accessed. Many projects had incomplete contracting, monitoring evaluation and review (MER) information and final report records within AWI and MLA, and much of the initial stages of this review were spent identifying, sourcing and collating information that was not archived in a way that enabled efficient retrieval. While AWI and MLA both provide final project reports on their websites, specific information is difficult to locate efficiency. That is, it is not curated in a way that enables a simple search to reveal the latest research using broad search terms, and nor is there any alert system for subscribers to share the latest information and reports as they become available. Without a dedicated curated and easily searchable database that alerts subscribers to new information, it is difficult to keep next users and end users up to date with developments in sheep reproduction[25].

10.3.3.2 Allocate resources to the design of adoption pathways

Other frequent comments made by stakeholders during this review were that:

- The adoption pathway for research is not often identified at the beginning of projects.
- The outcomes from research are not being simultaneously developed into adoptable products.
- The products are not being tested on-farm to assess their applicability in different systems.
- There is no feedback loop from adoption back to research.

RD&E is still viewed as a linear process from research concept to proposal to project to outcomes to extension design to extension delivery to adoption. However, it is not a linear process, with learning and insights at all stages influencing what will be adoptable, and thus influencing experimental design and development of extension messages. Ideally, all research projects should be designed to incorporate extension and adoption stages (using appropriate specialists) with provision of

[25] While MLA's Feedback magazine and AWI's Beyond the Bale do feature stories about RD&E, they are of a general nature that do always provide linkages to the final report, key researchers or further detailed information that is required to lead to adoption. They are at best a 'heads up'. These publications are also primarily targeted at producers rather than next users whose information needs are typically more complex.

appropriate investment to enable development of the extension component. Currently, there is a perception that adding extension and adoption into research project budgets is too expensive to fund, therefore extension tends to be 'left for later', which often does not eventuate as people move on to the next project. There is also a perception by some that extension is being designed by people with theoretical knowledge of farming rather than those that work with producers on a regular basis (next users), resulting in less effective extension program design.

10.3.3.3 Review outcomes by next users to ensure they are adoptable in a broader context

There is considered to be merit in reviewing research results using the next users (not just the relevant RDC project manager/s) to enable value of the outcomes to be discussed in practical on farm adoption terms. Reviewing research projects that have involved extension experts in designing the extension/adoption approach is beneficial as it can highlight gaps and issues with the approach when it is being extended in different systems. It would also provide benefits via:

1. Improved rigour in results, readability of final reports and adherence to consistent reporting formats to allow for greater utility of information and data interpretation.
2. Improved awareness and understanding of outcomes by a broader audience of industry experts.
3. Enabling next steps in adoption pathways to be planned and tested.

Recommendation 14: *Increase the proportion of investment allocated to developing and extending research outcomes to enable more next and end users to benefit by:*

- *Investing in a curated database to store all sheep reproduction RD&E project reports, including contact details for each project to enable follow up of outcomes. This database needs to be easily searchable and accessible to all stakeholders. Investment needs to cover maintenance and communication of contents widely to improve awareness across the industry.*
- *Prioritising allocation of sufficient resources to ensure that an adoption pathway is established for all extension and adoption messages at the beginning of a project utilising input from extension specialists.*
- *Reviewing R&D projects with adoptable outcomes by next users to determine extension/adoption messages, extension adoption pathway, target audiences (next users and end users) and what additional work is required to ensure that information/messages are:*
  - *Locally relevant*
  - *Economically viable*
  - *Applicable to the spectrum of different sheep business types i.e. Merino self-replacing, non-Merino terminal flocks etc, different lambing times, specialist versus mixed enterprise sheep farms, intensive versus extensive production systems.*

10.3.4 Design and delivery of extension and adoption

This review found that in addition to insufficient resources allocated to extending and adoption of outcomes from R&D, the way outcomes are extended to achieve adoption needs further investment. A research report published on an RDC website, or a peer reviewed paper in a scientifically reviewed

journal, are not adoption pathways to the end users of the outcomes, however that is the extent of communication for many R&D outcomes.

There is a spectrum of extension and adoption activities that can be designed and developed for different producer audiences depending on the R&D project output, the target audience and the extension/adoption outcome required. Examples include decision support tools, training (online and face to face), demonstrations, articles, fact sheets/guidelines, field days, workshops and longer-term group learning programs. This also includes building capacity and capability of next users to be part of the adoption pathway for end users. Most next users interviewed during this review reported that it is difficult to access the latest R&D outcomes (as mentioned above) or that when they did, they were not expressed in a way that made them easily extended (i.e. practically related to farming) or that they themselves needed assistance to interpret the messages in different contexts or in how to use the tools developed.

This review also found that all extension does not necessarily lead to adoption per say, that if adoption is the outcome required, more, new or improved extension methodology is required. This assumes that for adoption to occur, there is an on-farm issue or problem that needs solving that has been identified as a priority and is finically viable to solve. If this motivation is not evident, there needs to be a compelling case to adopt based on industry benefit that can drive adoption.

10.3.4.1 Develop capability and capacity of delivery networks

Many stakeholders reflected on the importance of demonstration on farm of new techniques and technologies so that producers had confidence that the investment would be worthwhile i.e. it works in their environment, in their systems using their limited resources. While training programs like LTEM are beneficial in teaching skills and monitoring impact of changes, there is a need to continue supporting producers to apply knowledge and skills consistently in variable conditions, and to monitor the results to achieve long lasting adoption. Whether this is achieved using a one to one approach that is akin to consulting/coaching, or whether it is through small group training with additional one to one support or demonstration site projects, it is evident that all three are key methods to achieving practice change, as opposed to just increasing awareness and skills building.

These three methodologies are deemed expensive in that implementation requires utilisation of extension specialists that are highly skilled and experienced, and it takes time (years) to see consistent results. The success of all three methods is dependent on simultaneous investment in:

- Awareness activities as a means of engaging producers to feed into the more intensive extension activities.
- Developing the capacity and capability of the delivery network, such as professional development of existing consultants/trainers/facilitators and recruitment and professional development of additional service providers.
- Defining the target audience to ensure that the producers who are likely to benefit most are engaged.

10.3.4.2 Design adoption pathways from end user back to R&D

This review found that extension was not often designed from the perspective of the target audience. Much extension is driven by new information dissemination rather than utilising a problem-solving approach. That is, identification of what the problem is on farm, what does the data show, why is it

worth solving and how to solve the problem, including analysis of the benefits/costs and practicality of implementation.

10.3.4.3 Invest in promoting extension and adoption programs/projects

This review has found that there needs to be more resources invested into promoting not only the adoption messages, but the extension products, to better engage the target audience. Most promotion is not directed specifically at the target audience, nor is past participation data utilised to better understand the potential audience. Promotion activities need to be evaluated to determine what is successful and what is not, and also to test new approaches, such as using social media influencers, and social media advertising targeted to particular audiences. There is a lot that can be learnt from the way professional development is promoted in other industries outside of agriculture, and how data from past program participants can be analysed to improve marketing and promotion of extension.

Recommendation 15: *Investment be made in designing extension activities to achieve adoption by the target audiences, including next users, that aims to solve well defined on-farm problems:*

- *Each R&D adoptable output (product) adoption pathway includes:*
  - *Extension method (awareness raising activities, training programs, workshops, demos, news articles, one to one or group, events etc);*
  - *Definition of target audience (next and end users); and*
  - *Capacity and capability building of delivery network.*
- *Adoption programs explore and define the required outcome from the end user's perspective before promoting the details of the program methodology:*
  - *What is the issue the program addresses?*
  - *How do producers determine whether it is an issue for them or not?*
  - *What is the impact of the issue on their farm and therefore is it worth solving, including prioritization of alternative changes, is it profitable to solve, and other benefits of solving the problem?*
- *Invest in promotion and marketing of extension programs beyond word of mouth and traditional forms of advertising. This includes analysing participation data to inform approaches.*

10.3.4 Continuous improvement and evaluation

Throughout this review it was difficult to find and utilise evaluation data for many of the projects assessed. In some cases, Monitoring, Evaluation and Review (MER) plans had been developed but followed through inconsistently (i.e. collected participation data but did not collate, analyse or report it), while for others no MER had been planned or no data had been collected. Some projects have collected the data (e.g. Making More from Sheep) but the database has not been interrogated in a way that yields answers to questions about target audiences and the impact of the extension activities.

Many of the projects reviewed lacked sufficient data to demonstrate adoption and impact in terms that could be utilised to monitor success and to continuously improve project delivery in a structured

way. In addition, very little evaluation is reported outside of the funders and project coordinators. Delivery staff, participants and the wider industry are often ignorant of the success of the program in objective terms. If producers and deliverers are unaware of what a project has actually achieved, they are less likely to value evaluation data collection processes.

10.3.5.1 Implement MER plans that include engagement, adoption rates and impact

M&E for adoption programs can be thought to have two aims:

1. To evaluate the success of the event/program against the project aims and plan i.e. did it engage the right audience, did the event/program deliver a quality experience, did the audience learn what was intended, did the program utilise resources effectively, was it fit for purpose?
2. To determine the impact of the event/program on participants i.e. did participants take the action the program was designed to deliver and if not why not, and did the action result in the productivity and economic outcomes intended?

In the majority of extension programs evaluated for this review, the MER was designed to evaluate the success of the event or activity, but few had processes to measure the impact of the event/activity on participants post program, and even fewer could demonstrate how this information was utilised to improve the outcomes of the project. There was also little evaluation of whether a program was 'fit for purpose', that is, achieved the adoption and impact it set out to achieve.

In most cases the evaluation data collected to demonstrate impact was self-reported by producers at a single point in time, with no data validation undertaken. While this is the simplest and cheapest means of assessing impact, it also lacks veracity relative to a process such as that utilised for the evaluation of the MLA Majority Markets Program (MMP) (Howard *et al*., 2014). This evaluation was conducted over a three-year period to track results from producer implementation of a range of practice changes over time, and involved assessment of impact at a whole farm level assessed via the collection and analysis of benchmarking data on farms. The MMP evaluation found that the vast majority of producers over-estimated the expected long-term productivity improvement of practice change adoption relative to the actual validated results measured over several seasons. While this type of approach will not be suitable for evaluation of all programs due to the time and cost involved, it would be appropriate for the larger, longer term extension programs such as LTEM.

It was identified by stakeholders during the review process that more often than not, project/program evaluation is undertaken by individuals who have also been involved in, or been responsible for, project development and/or delivery. Particularly for the larger project investments carried out over a longer period of time, such as LTEM and Bredwell Fedwell, it is considered to be more appropriate for project evaluations to be conducted independently of project involvement.

10.3.5.2 Share MER results with all stakeholders

One of the issues with evaluating extension and adoption stems from lack of clarity around key performance indicators (what is being measured and why) and data collection processes that are complicated or impinge on the activity. The purpose of the evaluation might be clear to the project managers, but to the deliverers it is often viewed as another task that adds little value to the activity, and as a result, is not always carried out completely or accurately. Part of the observed deliverer ambivalence in collecting accurate data is related to the fact that project managers do not feedback the results in a form that is useful to the deliverer and the program participants.

In addition, extension and adoption projects need to report characteristics of who was engaged, adoption rates, including what was adopted and the impact of adoption, and compare these figures to initial targets to regularly report progress to all stakeholders to drive continuous improvement. In our experience, this information is rarely passed on to deliverers in a collated and analysed format that informs and engages the deliverers in continuous improvement of project delivery. Participants are rarely engaged in evaluation in a way that is meaningful to them. Use of clickers and polls in some projects (e.g. Bredwell Fedwell) are positive activities to provide evaluation transparency, but this is one of the few programs that utilises these methods for data collection and reporting.

Recommendation 16: *MLA and AWI invest in the development of consistent MER frameworks to monitor performance of projects in addition to measuring impact and adoption that feeds into continuous improvement processes:*

- *Investing in the development and implementation of consistent MER for all extension projects/programs that reports on the success of the event/activity in terms of participation as well as adoption and impact of the project/program on farm.*
- *Where possible, and particularly for larger projects, invest in processes to collect and validate impact data from producers over multiple seasons to more accurately assess long term impact.*
- *Project/program evaluations be conducted by independent providers outside of project/program development and delivery activities.*
- *Sharing evaluation results with all the project stakeholders including delivery staff, participants and other interested stakeholders. The aim is to:*
    - *Inform deliverers and participants of project achievements and shortcomings and provide feedback/validate their input (and may contribute to increased accuracy of evaluation data collected and results) and to demonstrate progress made.*
    - *Provide stories and data to further promote projects to other potential next users/end users and target audiences.*
    - *Justify investment of levies to producers by highlighting achievements.*

11.0 Industry Collaboration on Sheep Reproduction RD&E

Sheep reproduction is an area of RD&E where objectives and outcomes apply to all sheep, regardless of breed or production system. MLA and AWI have therefore endeavoured to collaborate in this area in an effort to reduce duplication and maximise value from available funding and resources for producers. One of the objectives of the current impact assessment was to assess the effectiveness of industry collaboration in sheep reproduction RD&E and to make recommendations for improvements. This process involved collection of feedback from stakeholders based on their experiences with collaboration in this area, and discussions with relevant MLA and AWI staff for their views on the effectiveness of collaborative efforts.

The following section provides a summary of key findings from the stakeholder engagement process presented in the form of a SWOT analysis (strengths, weaknesses, opportunities, threats), however rather than ‘threats’, ‘challenges’ associated with achievement of more effective collaboration have been identified. This is followed by a discussion of key issues and a section on suggested recommendations for improving both the effectiveness and efficiency of future collaboration between MLA and AWI and between service delivery partners.

11.1 Key Findings from Collaboration Analysis

Strengths

The stakeholder engagement process identified the following strengths regarding industry collaboration on sheep reproduction RD&E:

- Development of the National Sheep Reproduction RD&E investment Plan (2012-2017) is viewed positively;
- A shared industry focus on improving sheep reproduction outcomes, and in particular, an agreed focus on increasing lamb survival;
- Both formal and informal collaboration on sheep reproduction RD&E between MLA and AWI has improved over the past 7 years; and
- A general willingness among most RD&E delivery service providers to collaborate on projects as multiple delivery partners.

Weaknesses

The stakeholder engagement process identified the following weaknesses regarding industry collaboration on sheep reproduction RD&E:

- A perceived lack of shared understanding across industry sectors as to what 'success' looks like;
- A lack of alignment of industry investment in RD&E with the SRRIP and a lack of monitoring of investment relative to the SRRIP;
- A lack of commitment by AWI in withdrawing funding from some projects;
- Some crossover in project investments and some missed opportunities for collaboration between MLA and AWI on some issues;
- A lack of sufficient breadth of collaboration across industry RD&E delivery organisations;
- Insufficient opportunities for collective gathering and sharing of ideas between MLA/AWI and RD&E service providers;
- Difficulties associated with project management and IP arrangements with collaborative project investments and for projects with multiple delivery partners;
- Insufficient engagement with advisors and consultants and less than ideal levels of collaboration between research providers and extension service providers; and
- Lack of sufficient focus on building the long-term capacity and capability of extension service providers.

Opportunities

The stakeholder engagement process identified the following opportunities regarding improvement of industry collaboration on sheep reproduction RD&E:

- Development of a new national sheep reproduction plan;
- Increased project co-investments between MLA and AWI;
- Facilitating opportunities for researchers to share ideas while protecting the source of these ideas (IP);
- Streamline project management and IP structures and processes;

- Increase engagement between research providers and extension service providers/consultants and between research providers and producers via consultants/advisors;
- Increase the breadth of producer consultation and engagement beyond the SALRC and WALRC committees to involve more 'regular' producers;
- Collaborative opportunities with new sectors and expanding collaboration with other sectors e.g. International, environmental, commercial sector, education sector (secondary and tertiary);
- Further incentivise collaboration for researchers and consultants;
- Greater breadth of engagement across industry by MLA and AWI for RD&E service delivery; and
- Greater focus on building the capacity and capability of extension service providers in the area of sheep reproduction.

Challenges

The stakeholder engagement process identified the following challenges regarding improvement of industry collaboration on sheep reproduction RD&E:

- Managing industry expectations for what 'success' should look like;
- Availability of funding, particularly from AWI given the recent decrease in the wool levy and wool price downturn;
- Managing IP issues to ensure maximum utility for producers from RD&E outcomes;
- Limited pool of researchers/consultants in sheep reproduction with required knowledge, skills, facilities and resources for delivery of RD&E;
- Managing the impact of staff movements within MLA and AWI to minimise negative impacts on commitment to implementation of a national sheep reproduction plan; and
- Higher project management costs and reduced timeliness of project commencement for collaborative projects.

11.2 Discussion of Key Issues around Collaboration

Stakeholder feedback provided during the review process indicates that the focus and effort on collaboration between MLA and AWI was observed to have improved over the past seven years or so, but that there are opportunities for further improvement. The vast majority of stakeholders indicated a desire for more industry collaboration on the issue of sheep reproduction in the future, however many also acknowledged that there are various challenges associated with achieving successful collaboration.

11.2.1 Amount of RD&E Collaboration

Figure 31 indicates that almost 60% of all sheep reproduction projects were funded by MLA, compared to a third by AWI and 10% of projects with co-funding from both MLA and AWI. The relative size of available R&D budgets for MLA and AWI are provided in Tables 6 and 7 respectively in section 6.3, noting the higher availability of R&D funding within MLA compared to AWI. As identified in Figure 13, the total funding for MLA/AWI collaborative projects has accounted for only 8% of all expenditure on sheep reproduction RD&E.

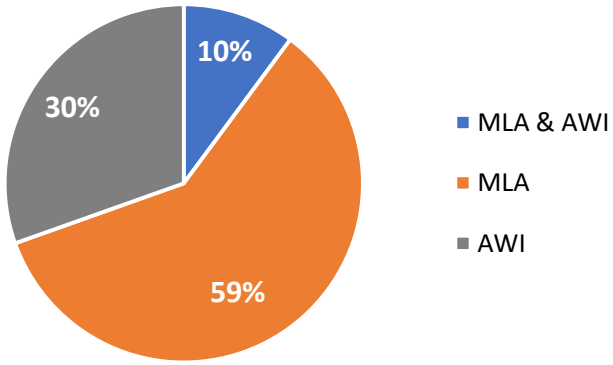


Figure 31: Percentage of all sheep reproduction projects evaluated by RDC funding source

Finding 32: *Since commencement of the SRRIP, only 8% of all industry investment (and 10% of all projects) has involved collaboration between MLA and AWI, supporting stakeholder feedback suggesting that there is an opportunity for greater collaboration between MLA and AWI in the future.*

Although the level of formal collaboration between MLA and AWI at a project investment level was considered by most stakeholders to be less than ideal, the review process found that a considerable amount of informal collaboration occurs between MLA and AWI in the area of sheep reproduction. Informal processes involve regular phone and email communication between MLA and AWI personnel to discuss project investments, areas of interest for future investment, sharing of research findings and reports, sharing of open call project applications, discussion of opportunities for co-investment in areas of mutual interest and identification of areas where only one organisation is interested in pursuing to minimise duplication of effort.

MLA and AWI have also recently commenced a process of requesting permission from open-call applicants to share their proposals with other organisations where it is considered that the outcome for producers would be enhanced by combining elements of proposals which are considered similar enough to warrant it. The purpose of this process is to create a better research investment than any individual proposal is considered to have provided.

Finding 33: *Considerable informal collaboration occurs via communication on a regular basis between MLA and AWI sheep reproduction management personnel to share information and ideas, to identify opportunities for potential project collaborations and to reduce the potential for duplication of research and extension efforts.*

Table 23 reveals that the majority (59%) of all sheep reproduction projects funded between July 2012 and December 2019 have involved collaboration between multiple delivery organisations. Forty-one percent of projects have involved just one delivery organisation, however often with multiple individuals from the organisation involved.

Table 23: Proportion of research projects by funding source with single versus multiple delivery partners (excludes extension programs)

	MLA Funded	AWI Funded	MLA & AWI Co- Funded	All Projects
Projects with 1 delivery organisation	28%	76%	25%	41%
Projects with multiple delivery partners	73%	24%	75%	59%

MLA funded projects and MLA/AWI co-funded projects have involved multiple delivery partners in approximately three-quarters of all projects, in contrast to AWI projects where only around a quarter have involved collaboration between multiple delivery organisations. Projects involving more than one delivery organisation were typically larger projects, involving on average a 68% higher project budget compared to projects with just one delivery organisation.

11.2.2 Benefits Associated with RD&E Collaboration

Stakeholder feedback indicated that the key opportunities for industry to benefit from increased collaboration between MLA and AWI at a project investment level include:

- Reduced duplication of effort
- Increased sharing of ideas, knowledge and networks
- Wider network of extension pathways to share information with producers
- Increased return on total producer levy funds invested
- Collaboration is viewed positively by industry

The review of projects funded in the area of sheep reproduction indicates several areas where some level of crossover could have been avoided had AWI and MLA taken a more collaborative approach to investment (e.g. impact of ewe hormones and supplements on reproductive rate), however it is noted that in some cases AWI has had limited funding available during different periods of time to contribute to projects where co-funding would have been of benefit to both organisations. It also appears that there is some duplication between MLA and AWI funded R&D and R&D conducted by research organisations without any involvement of the RDCs. As such, the issue of shared industry communication regarding what R&D is being undertaken across all organisations, regardless of funding source, was identified as an area that could be improved to assist with minimising duplication of effort more broadly.

Finding 34: *Stakeholder feedback indicates a need for greater sharing of information regarding the status of what R&D is being undertaken across industry, regardless of funding source.*

Recommendation 17: *MLA and AWI to engage with research providers to investigate opportunities for provision of a centralised source of information on the status of sheep reproduction R&D regardless of funding source.*

In addition to feedback from stakeholders that greater collaboration between MLA and AWI is desirable, stakeholders had mixed views regarding collaboration between delivery partners on individual projects.

Many stakeholders reported positive experiences with involvement in projects with multiple organisations as delivery partners, citing the benefits as including:

- Increased ability to provide a highly skilled group of individuals relative to what skills might be available within any one organisation;
- Allows for sharing of facilities and equipment which may otherwise not be accessible;
- Increased diversity of backgrounds and experience creates new ideas and approaches to issues and therefore assists to generate higher quality project outcomes;
- Provides opportunities for less experienced members of an organisations to gain insights into how other organisations operate and exposes them to a broader range of skills and knowledge;

- Creates a shared sense of responsibility for achievement of project outcomes rather than one individual or organisation bearing all of the risk and responsibility;
- Assists to reduce duplication and to leverage greater value from the limited funding available;
- Assists to maintain capability and capacity within organisations in the sheep reproduction field;
- Creates greater buy in of the results if more people are involved;
- Enables R&D across different environments and systems by having more organisations involved on a project, and assists with understanding of application of R&D outcomes across different regions;
- Provides opportunities for individuals who may be working alone, or with few colleagues, to mix with interesting people and ideas which assists to build motivation and creative thinking; and
- Sharing of knowledge and resources assists other organisations to learn from previous work more easily.

11.2.3 Challenges Associated with RD&E Collaboration

While many stakeholders reported value in collaboration with other organisations, others identified various challenges associated with this process:

- Arranging contract terms and conditions can be a time consuming and costly process depending on the scale of the project and the number of organisations involved;
- Determining the IP arrangements for projects can be very difficult, particularly where multiple agencies are involved;
- Increased risk of sharing ideas with other organisations in terms of those ideas being 'stolen' and later funded;
- Challenges associated with managing variation in operational processes and procedures between organisations;
- Challenges associated with working with differing personalities and variations in levels of individual commitment to achieving project outcomes on time; and
- Limited financial reward from collaboration unless the investment has sufficient scale, which is not often the case.

It was also noted by some stakeholders that there was a disproportionate amount of project funding consistently provided to a relatively small proportion of delivery organisations. It was further commented by some that it was challenging for some individuals and organisations to be engaged in delivery collaborations if they were not linked in to this informal network who regularly collaborate with the RDCs.

In providing this feedback, some stakeholders also acknowledged that there is variability in the skills and ability of individuals across the sheep reproduction R&D sector in delivering required project outcomes on time, and that there are also limitations associated with the capacity of organisations to provide the required facilities and equipment for some areas of R&D, which could influence decision making for awarding of funding between alternative providers.

Finding 35: *Stakeholder feedback indicates concern that a disproportionate amount of MLA and AWI sheep reproduction R&D funding is provided to a relatively small proportion of delivery organisations and individuals which limits the potential for maintaining and building R&D capacity and capability and increases risk.*

Recommendation 18: *MLA and AWI to review the potential for increasing the breadth of engagement with service delivery providers with the objective of ensuring that all relevant sectors are engaged, and to ensure the sustainability of capacity and capability within and across organisations involved in sheep reproduction R&D delivery.*

Individual producers or producer groups have been involved in 16% of all projects, including PDSs, while only five non-producer commercial businesses have been involved in delivery of R&D in 8% of project investments. There have only been three international organisations involved in project delivery. The feedback from stakeholders for this review indicates a perceived opportunity to engage more commercial sector investors and delivery partners in sheep reproduction RD&E, and also an under-utilisation of engagement with RD&E occurring internationally, not just in the area of sheep reproduction, but also in other areas where it is suggested there are parallels, such as human medicine and research into other animal species.

Finding 36: *Only five non-producer commercial businesses have been involved in delivery of sheep reproduction RD&E in 8% of projects since mid-2012, and there have only been three international organisations involved in project delivery over the same period of time. Stakeholder feedback indicates that there is an opportunity to increase engagement with both the commercial sector and international R&D providers to add value to sheep reproduction outcomes in Australia, and also with the education sector (secondary and tertiary) to engage with and influence the next generation of producers as early as possible.*

Recommendation 19: *MLA and AWI to actively identify and explore potential opportunities to engage more with the education sector (secondary and tertiary) to establish a relationship with and influence the next generation of producers as early as possible, and with commercial enterprises and international RD&E providers to partner with for sheep reproduction RD&E.*

Stakeholders also identified an opportunity to leverage funding from environmental sources given the increasing importance of this issue among consumers, and the link between increasing sheep reproduction and decreasing the carbon footprint per unit of product output. These sources of funding could include accessing additional funds from within MLA and AWI allocated to achievement of environmental outcomes (as previously identified), engagement with environmental funding sources such as Landcare, Catchment Management Authorities (CMA), Land and Water Australia (LWA) or corporate organisations that have environmental goals and KPIs as part of their strategic plans.

Finding 37: *There may be opportunities for attracting funding for sheep reproduction RD&E from environmental funding sources where RD&E outcomes that contribute to increasing environmental stewardship from sheep production systems can be demonstrated.*

Recommendation 20: *MLA and AWI to identify and explore potential opportunities for collaboration with organisations and programs with environmental objectives, such as Landcare, CMAs, LWA and corporate businesses, in areas of sheep reproduction RD&E where environmental benefits can be demonstrated (e.g. increasing lamb survival and increasing reproductive efficiency of ewe lambs to decrease the carbon footprint per unit of product output).*

11.2.4 Opportunities for Improved Industry Collaboration

While there are clearly benefits associated with collaboration between MLA and AWI and between RDCs and delivery partners at a project investment level, it is important to consider the additional costs associated with achieving that collaboration. How much collaboration should there be is an important question given that collaboration takes considerably more time and resources to arrange and manage. The simpler the administrative and project management processes are for collaborative investments, the more collaboration between organisations can be justified on a cost benefit basis.

11.2.4.1 Project management and IP arrangements

During the stakeholder engagement process for this review it became apparent that there are several key areas where administrative and project management processes for collaborative projects could be improved.

While most stakeholders reported general satisfaction with the effectiveness of project management structures where multiple funding and/or delivery partners were involved, some commented on difficulties associated with establishing agreed contract terms and conditions in a timely manner. Rather than project management structures and arrangements, including terms and conditions of contracts, being determined on a project by project basis, it was identified that a more structured pre-defined framework could reduce the time required to establish and agree upon terms and conditions.

In addition to defining project terms and conditions, the majority of stakeholders engaged for this review felt that the issue of managing IP arrangements could be a difficult, expensive and time consuming process, depending on the type of research involved, the number of parties involved, and the organisations involved (some organisations were reported to be more difficult to establish IP arrangements with than others). Feedback also suggests that there is a general lack of clarity around the purpose of IP arrangements at both the RDC and delivery organisation level. Improved communication of the purpose of MLA and AWI IP arrangements may assist to reduce the amount of time and effort required in negotiating IP on a project by project basis.

It is also apparent that in some cases IP arrangements have hindered the ability of industry to fully utilise the outcomes from research projects. The sheep reproduction RD&E projects evaluated for this review have been ranked according to the ability of all parties to utilise the outcomes on an ongoing basis. This ability has been ranked according to four levels:

- Level 1: Restricted – no ongoing usage
- Level 2: Restrictive – ongoing usage for extension and communication purposes only
- Level 3: Flexible – ongoing usage for RD&E activities (excluding commercialisation)
- Level 4: Open – full freedom of usage

Figure 32 presents the proportion of projects categorised for each level of outcome utility.

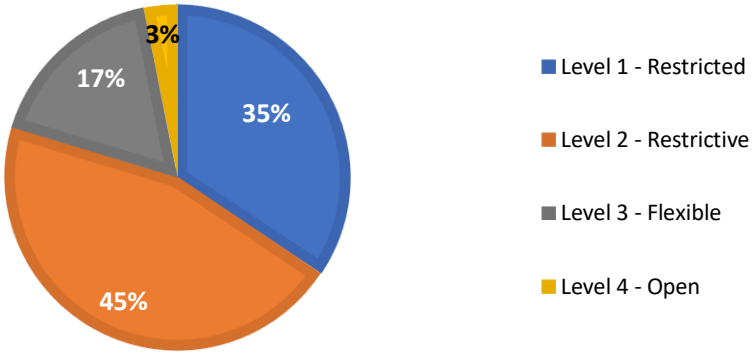


Figure 32: Proportion of sheep reproduction RD&E projects according to the level of ability for all parties involved to utilise the project outcomes on an ongoing basis

The default level for both MLA and AWI contracts is Level 2, with adjustments from this position negotiated between parties as required depending on the type of research and the expected outcomes. In some cases IP from project outcomes is shared with delivery organisations according to project contract terms, while in other cases a licensing agreement is required by the delivery partner which typically requires that the funding organisation be fully acknowledged and the licensee agrees to provide a report upon request to the funding body regarding utilisation of the IP identified in the licensing agreement. These reports may be required for the purpose of internal reporting or auditing, but are rarely requested.

For both MLA and AWI, a key principle in determining project IP arrangements is to enable RD&E outcomes to be utilised by industry, while also ensuring appropriate acknowledgement of the funding source which enabled generation of those outcomes, and minimising any mis-use of the outcomes. There have been instances where delivery organisations have utilised data collected via MLA and AWI funding without the knowledge and/or permission of the funding body and/or without providing acknowledgement of the source of the data. Both MLA and AWI take the position of a willingness for industry to utilise project outcomes beyond the project contract terms, however based on a duty of care, they need to ensure that the information is utilised appropriately and in the best interests of levy payers. Thus, they expect to be aware of how IP is being used, and for acknowledgement of that use so that they are able to better assess and report on the total value of outcomes generated from investment in RD&E to levy payers.

Finding 38: *There is an opportunity to minimise the financial costs and the additional time associated with achieving collaboration while maximising the utility of project outcomes for producers by:*

- *Simplifying the process of project contracting between RDCs; and*
- *Clarifying the objectives of IP and simplifying the process of determining IP arrangements.*

Recommendation 21: *MLA and AWI to establish agreed processes and principles for project management and IP arrangements for all projects delivered as part of the National Sheep Reproduction RD&E Investment Plan:*

- *MLA and AWI to develop a consistent framework for defining terms and conditions for co-funded project investments as opposed to terms and conditions being developed and agreed to on a project by project basis. This may involve differentiating the process required depending on the type of investment, particularly where project outcomes involve commercialisation of a product or process compared to more knowledge-based project outcomes.*
- *MLA and AWI to develop a set of key principles around the objectives of IP arrangements for project investments, to communicate these principles to funding partners and utilise them to guide development of IP arrangements at the project level. Suggested guiding principles could include:*
    - *IP arrangements should enable maximum utility of project outcomes for industry;*
    - *Delivery partners who do not provide funding to the project (either in-kind or cash) require a simple licensing agreement to utilise any IP generated from the project which is not publicly available beyond the terms of the project contract;*
    - *IP arrangements should ensure fair treatment of all funding partners in division of ownership of IP generated by project activities; and*
    - *IP arrangements should limit background and third-party IP to the minimum required for the project to simplify contracting processes.*

11.2.4.2 Incentivising collaboration and sharing of ideas for RD&E

One of the challenges for industry in maximising the benefits to producers from collaboration is providing incentives for service providers to share ideas and collaborate on projects within a framework that protects the IP of individual organisations.

Many stakeholders feel that there are insufficient opportunities for RD&E service providers to gather in person and 'brainstorm' ideas for addressing specific issues or priority areas identified by industry. However, while supportive of the need for this process, some stakeholders reported a reticence to share ideas at industry forums for future RD&E priorities as they had previously had what they felt were 'their ideas', taken by other organisations and later funded. As a result, R&D collaborations tend to be more around resource sharing to broaden the scope of work and/or to provide the skillset required to attract funding, rather than for pure scientific collaboration.

The recent call by MLA for strategic partnerships in sheep reproduction was viewed by stakeholders as being a step in the right direction towards incentivising collaboration between service providers, however it remains to be determined as to how this partnership will operate in practice to facilitate collaborative RD&E. It was suggested that it would be important for the effective operation of this partnership that member's ideas were protected in some way or that sharing of ideas was linked to subsequent project funding.

It appears that the current decision-making process regarding when and how AWI and MLA collaborate on sheep reproduction projects is fairly informal and unstructured, thus there may be an opportunity

for increased collaboration by developing a more formal framework for MLA and AWI decision making around co-investments. It was suggested by some stakeholders that a model of collaboration similar to that provided by the Sheep CRC would assist to incentivise collaboration between organisations in a more structured and cost-effective way. It was however, acknowledged that such a model would require funding to establish and maintain, and that this funding may not currently be available within the industry.

Finding 39: *To facilitate more effective collaboration in the future there is a need to further incentivise service providers to collaborate with one another and with MLA and AWI, and to create a more strategic approach to decision making by MLA and AWI around co-funding of sheep reproduction projects.*

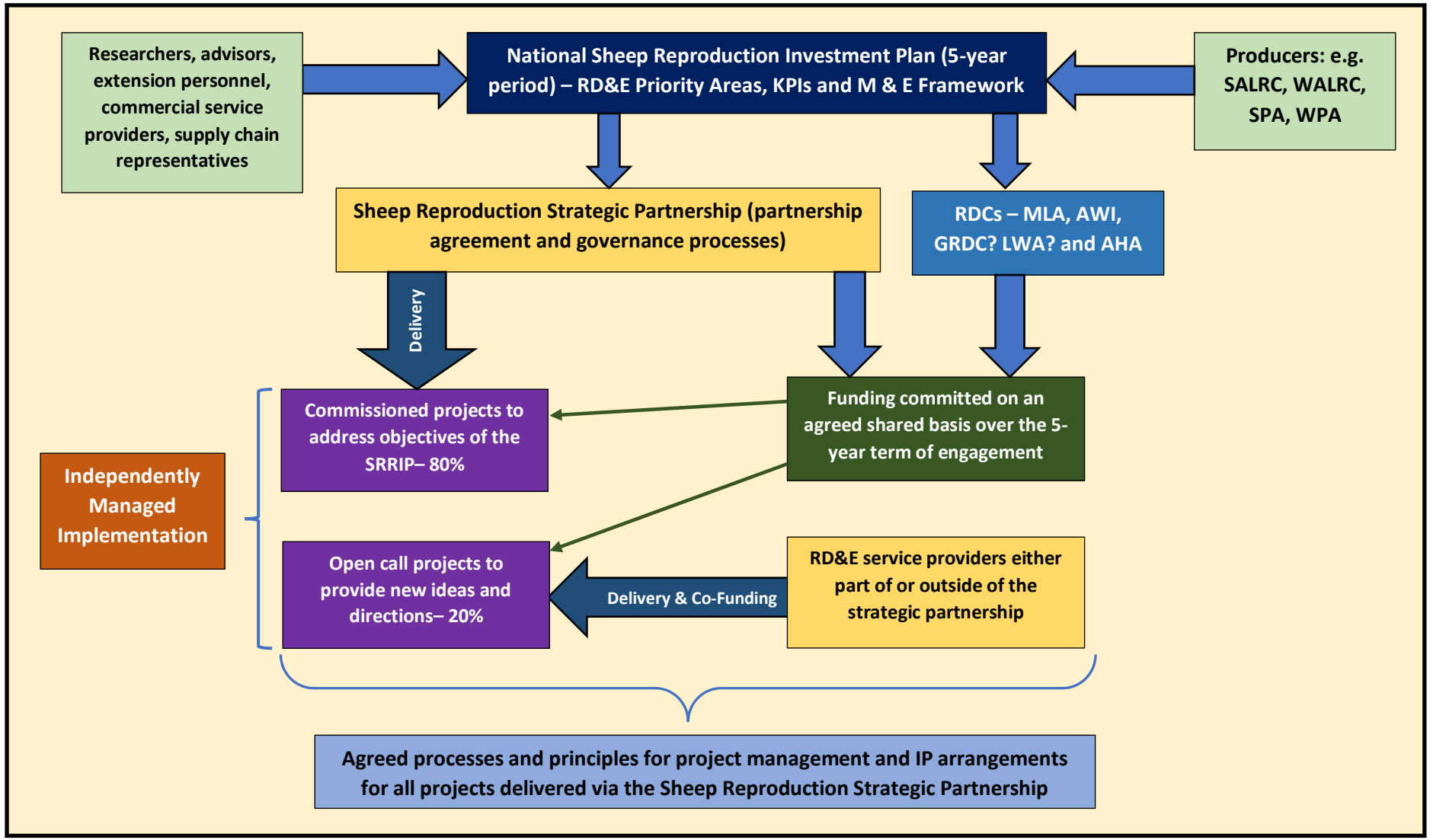
The following recommendations are made based on the assumption that a new National Sheep Reproduction RD&E Investment Plan will be developed in the near future.

Recommendation 22: *Increase the potential benefits from collaboration by increasing the incentive for industry partners to co-invest and share ideas, and provide a more structured framework for decision making around collaboration at a strategic level by:*

- *Establishing large programs of work which extend over the period of the SRRIP and which align with the priorities identified in the SRRIP;*
- *Identifying strategic partners who are willing and able to commit co-funding for each program area under agreed arrangements (via the Strategic Sheep Reproduction Partnership process currently in motion) to deliver required outcomes according to SRRIP KPIs;*
- *Engage with relevant strategic partners to develop projects to address the key priority areas within each program;*
- *Allocate approved project delivery activities within each program to strategic partners according to project requirements, co-funding committed and availability of relevant skills, knowledge, infrastructure and equipment within partner organisations. The emphasis should be on collaboration where this creates benefits, but also involve a willingness to make strategic decisions not to collaborate in instances where it is not considered cost effective to do so;*
- *Where required, engage service providers outside of the strategic partnership where additional skills, knowledge or experience for achievement of project outcomes are considered to be necessary;*
- *In addition to commissioned projects developed to align with achievement of SRRIP objectives, a portion of total available funding be committed to an open-call process for projects to facilitate generation of new ideas and research directions; and*
- *At the RDC level, based on available funding, MLA and AWI identify their priority areas for funding allocation, and where these areas cross-over, co-funding arrangements are implemented. This may be at a program investment level, or if more delineation of investment areas is required, at the project level.*

Figure 33 provides a possible framework for future industry collaboration.

Figure 33: Possible framework for future sheep reproduction collaborative RD&E delivery



12.0 Conclusion

The purpose of this review was to assess the benefits, costs and impacts of current and recently completed RD&E activities in sheep reproduction and lamb survival against key industry performance targets. The review also involved an assessment of industry collaboration on sheep reproduction and identification of remaining gaps in sheep reproduction RD&E. A total of 120 project investments were assessed during the review. The review also involved engagement with a range of industry stakeholders who have been involved with design and delivery of sheep reproduction RD&E during the delivery period of the SRRIP, in addition to feedback obtained from producers. Fifty-one industry stakeholders were interviewed by phone and 49 producers provided input via an online survey.

The stakeholder engagement process indicates broad industry support for having a National Sheep Reproduction RD&E Investment Plan, however it was found that the SRRIP was not implemented effectively nor utilised as an ongoing focus for prioritisation of sheep reproduction project investments during the review period. It was identified that for a new SRRIP to be successfully implemented it would require formal commitment from all industry partners for the duration of the planning period.

Total investment in sheep reproduction RD&E for projects contracted during the SRRIP investment period (2012/13 to 2016/17) was $20.71 million, which is 16% less than the $24.70 million recommended investment in the SRRIP. According to stakeholder feedback, relative to the perceived importance of the issue of lamb survival to the sheep industry, the level of funding allocated by the RDCs to sheep reproduction RD&E, particularly to development and extension activities, is considered to be inadequate to achieve the desired industry outcomes for lamb survival. It was estimated that had the actual investment amount in projects included in the impact assessment for this review been apportioned between pillars according to the recommendations in the SRRIP, and assuming the same B:C ratio by pillar was achieved for reallocated funds, an additional $6.62 million in net present value terms would have been generated from that investment. With removal of one outlier project from the analysis to provide a more representative overall assessment, the estimated additional net present value foregone increases to $12.68 million.

The overall objective of the SRRIP for a 2% average annual increase in sheep reproduction rate over the 5-year planning period was not achieved, with the average annual rate of gain during the SRRIP period being between 0.6% and 1.5%, depending on the source of data utilised. This rate of gain was highly likely to have been negatively influenced by below average seasonal conditions during the SRRIP implementation period. The average annual national rate of gain in marking rates during the SRRIP delivery period was between 1.0% and 1.4% for Merino lambs and between 0.6% and 1.7% for all other lambs, again depending on the data source.

The impact of project investments where an adoption output and an adoption pathway were evident ranged between zero and $3.91 per ewe. Utilising a 5% discount rate over a 25-year time period, the economic assessment of all projects where an adoption output and an adoption pathway were evident returned an NPV to industry of $93.40 million with a BC ratio of 5.2 and an internal rate of return of 39%. A sensitivity analysis of the impact assessment found that with a 20% higher rate of productivity gain and a 20% higher value of additional lambs weaned, RD&E investment returned an NPV of $197.84 million and a B:C ratio of 9.9, and with a 20% lower rate of productivity gain and a 20% lower value of additional lambs weaned, the NPV was $19.21 million with a B:C ratio of 1.9.

Since commencement of the SRRIP, 8% of all industry investment (and 10% of all projects) has involved collaboration between MLA and AWI, and 59% of all projects have involved collaboration between multiple delivery organisations. Although the amount of formal collaboration between MLA and AWI was viewed by most stakeholders as being less than ideal, the review found that considerable informal collaboration occurs via regular communication between MLA and AWI sheep reproduction management personnel.

While the vast majority of stakeholders indicated a desire for more industry collaboration on the issue of sheep reproduction in the future, many also acknowledged that there are various challenges associated with achieving successful collaboration. Stakeholders also expressed mixed views regarding collaboration between multiple delivery partners on individual projects.

The review process identified a range of current gaps in sheep reproduction RD&E in addition to opportunities for improving industry collaboration on sheep reproduction in the future. A series of recommendations has been provided for addressing these gaps and for capitalising on identified opportunities.

Consultant acknowledgments

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Appendix A - Findings and Recommendations

Findings	Recommendations
Sheep Reproduction Key Performance Indicators	
Finding 1: As a single indicator for measuring change in sheep reproduction efficiency over time, lamb marking rate has several key limitations. **Finding 2:** With the exception of the WIRNS target relating to Lifetime Ewe Management, other than lamb marking rate, there is no national time series data available to measure success against any of the other numerical key performance indicators for sheep reproduction identified in industry strategic plans.	**Recommendation 1:** In setting KPI targets for improvements in sheep reproduction efficiency in industry strategic plans: • Include a range of KPIs which reflect the specific objectives of RD&E investments for increasing sheep reproduction efficiency (e.g. ewe mortality, ewe lamb conception rates, ewe fertility and lamb survival). • Ensure that there is data available to assess performance against all KPIs identified in strategic plans. • If no data is currently available to assess performance against a KPI, either remove the KPI from the strategic plan, or identify a means of obtaining the data required to measure change. • Acknowledgement be given and/or provisions made for the influence of seasonal variation on the ability to achieve targets.
Value Proposition for Increasing Sheep Reproduction Rate	
Finding 3: While increasing the size of the national sheep flock is a priority at a national level, it is not necessarily a priority for individual producers. At the farm level, increasing the size of the national flock is not an objective that influences decision making, and increasing reproductive rate will not necessarily lead to increases in the size of the national flock. **Finding 4:** Increasing animal welfare by increasing lamb survival is a high priority for the industry, however there is a conflict between increasing ewe fertility as a priority and the lower lamb survival of twin and triplet lambs in the extensive conditions on Australian farms.	**Recommendation 2:** Greater recognition by funding bodies of the trade-off between increasing ewe fertility and lower lamb survival among the additional lambs born, with subsequent greater clarity around the required balance between these two objectives at a strategic level to better inform and guide decision making for project investments.

Findings	Recommendations
Finding 5: Increasing community calls for reducing red meat consumption amidst concerns around greenhouse gas emissions has prompted the red meat industry to set a target of carbon neutral red meat production by 2030. Greater investment in increasing lamb survival and reproductive rate of ewe lambs are key opportunities to assist industry in meeting this target. **Finding 6:** Some of the extension messages provided to producers, particularly wool producers running self-replacing Merino flocks, by both consultants and the MLA Business EDGE program, are potentially counterproductive to the industry objective of increasing lamb survival. **Finding 7:** The level of lamb survival considered to be acceptable by society and consumers is likely to be higher than the collective level of lamb survival achieved on individual farms aiming to maximise farm profit within limited resource boundaries, thus representing a potential market failure which may require additional government and industry funding to address.	**Recommendation 3:** Industry to define and report on the impact of improving ewe reproductive rate on reducing the carbon footprint per unit of product output (wool and lamb). Identifying and promoting these benefits will add to the value proposition for increased investment in sheep reproduction in coming years to reduce the carbon footprint of both wool and lamb production, and to contribute to the 2030 goal of carbon neutral red meat production. **Recommendation 4:** MLA and AWI to engage with sheep consultants who are promoting messages which are potentially counterproductive to the objective of increasing lamb survival, and involve them in a process of creating greater clarity and information around the profitability or otherwise of improving ewe and lamb survival, as opposed to increasing ewe fertility, in a range of wool producing systems. This may involve: • Consultants participating as part of a demonstration on a client's farm to assess the impacts of practice changes to increase lamb survival. • Working with consultants to develop economic methodologies and agreed valuations of input costs to more accurately assess the value proposition of increasing lamb survival across a range of wool producing systems. These processes may show negative economic returns from increasing lamb survival in some systems, but the outcome would be more informed decision making for all wool producers, including those for which it is profitable to increase lamb survival, and a greater awareness of lamb mortality as an animal welfare issue, its causes, its costs and alternatives for its prevention. **Recommendation 5:** MLA to review and update the content of the Business EDGE workshop notes to ensure that it aligns with industry strategic objectives for lamb survival by: * Ensuring that messages are supported by economic data, including a transparent process for reporting of that economic data so that producers are able to insert their own values to assess profitability over time for their own businesses. * Include clarity around the difference between increasing ewe fertility and increasing lamb survival as different objectives and potential sources of increased profitability. * Include commentary on the value of increasing lamb survival from an animal welfare perspective regardless of marginal profits.

Findings	Recommendations
Industry Investment in Sheep Reproduction RD&E	
Finding 8: Total industry investment in sheep reproduction RD&E between 2012/13 and 2016/17 has been 16% less than that recommended in the SRRIP (2012-2017). **Finding 9:** The value of total industry investment in development and extension activities between 2012/13 and 2016/17 has been around two-thirds of that recommended in the SRRIP (2012-2017). **Finding 10:** Had investment in the projects included in the impact assessment for this review been apportioned between pillars according to the recommendations in the SRRIP, rather than what actually occurred, it is estimated that an additional $6.62 million in net present value terms would have been generated from that investment. With removal of one outlier project from the analysis to provide a more representative assessment, the estimated additional net present value foregone increased to $12.68 million. **Finding 11:** Total estimated industry investment since July 2012 in the 'Early reproductive success and weaner performance' pillar is around 70% of what was recommended in the SRRIP (2012-2017). Investment in all other pillars has exceeded targets identified in the plan. **Finding 12:** Total industry investment since mid-2012 in both strategic research, and more significantly, in development and extension, has remained less than that recommended in the SRRIP (2012-2017). **Finding 13:** Relative to what was recommended in the SRRIP, the proportion of total expenditure on sheep reproduction has been 83% higher on applied research, 40% lower on development and extension, and 55% lower on strategic research.	

Findings	Recommendations
Finding 14: In-kind and cash contributions from delivery organisations account for 35% of total investment in sheep reproduction RD&E since mid-2012. While cash contributions are accurately recorded on project contracts, valuation of in-kind contributions is less robust.	**Recommendation 6:** MLA and AWI work together to develop a consistent process for classifying, valuing and reporting in-kind contributions from delivery partners. This framework should be provided to all delivery partners where in-kind contributions are involved to increase the accuracy of these contributions. It is also recommended that MLA and AWI consider utilising a shared database of individual delivery personnel where in-kind FTEs are recorded against individuals to ensure that in-kind FTE contributions are not over-valued by double counting time.
Utilisation of the SRRIP to Guide Industry Investment Decisions	
Finding 15: The stakeholder engagement process indicates broad industry support for a National Sheep Reproduction RD&E Investment Plan. **Finding 16:** The stakeholder engagement process indicates a general consensus that the potential value of the SRRIP (2012-2017) has not been realised due to a lack of broad industry commitment and leadership around implementation of the plan. **Finding 17:** The SRRIP has not been effectively utilised over the term of its life to guide project investment decisions for sheep reproduction RD&E. Overall, there was a lack of resourcing to support ongoing governance planning and accountability to ensure that the SRRIP was effectively implemented and monitored to achieve its objectives.	**Recommendation 7:** A new National Sheep Reproduction RD&E Investment Plan be developed for commencement in 2020/21. The next version of the plan should: • Involve broad industry consultation across all relevant sectors and organisations; • Establish a clear purpose for the plan including industry outcomes that reflect all stakeholder needs; • Establish national objectives and KPI targets that align with the objectives of other relevant industry strategic plans; • Be developed/co-ordinated by an independent person/persons; • Involve utilisation of an agreed standard process for evaluating the potential economic benefits from alternative project investments; • Be accompanied by an operational plan for delivery and a monitoring and evaluation framework for assessing delivery progress against KPIs and to modify the direction of the plan if deemed necessary; • Be implemented under the direction of an industry representative steering committee of organisations and sectors committed to achieving the intended outcomes of the plan; and • Establish appropriate governance and accountability structures and processes for implementation, monitoring and evaluation.
Finding 18: For a new SRRIP to be successfully implemented it would require formal commitment from all industry partners for the duration of the planning period.	**Recommendation 8:** Establish formal commitment to implementation of a new SRRIP through a binding partnership agreement with all relevant partners to commit funds and resources to implementation of the plan for its duration.
MLA and AWI Investment in Sheep Reproduction RD&E	
Finding 19: According to stakeholder feedback, relative to the perceived importance of the issue of lamb survival to the sheep	**Recommendation 9:** MLA and AWI to review their level of relative investment in sheep reproduction RD&E in light of the perceived misalignment between the importance of the issue of lamb survival,

Findings	Recommendations
industry, the level of funding allocated by the RDCs to sheep reproduction RD&E, particularly to development and extension activities, is inadequate to achieve the desired industry outcomes for lamb survival. **Finding 20:** MLA expenditure on sheep reproduction RD&E represents around 4% of the available funding for RD&E to increase farm profitability and productivity. AWI expenditure on sheep reproduction has varied between years at an average of around 10% of total RD&E expenditure over the past 7 years.	particularly from an animal welfare perspective, relative to the proportion of RD&E funds invested in addressing the issue. **Recommendation 10:** MLA and AWI to explore the scope for increasing funding allocated to key areas of sheep reproduction RD&E, such as increasing ewe and lamb survival and increasing the reproductive efficiency of ewe lambs, on the grounds that outcomes from these areas of RD&E also contribute to organisational objectives for environmental and animal health and welfare outcomes.
Sheep Reproduction RD&E Achievements	
Finding 21: Since the inception of the SRRIP, there has been a considerable amount of sheep reproduction research and development which has generated new knowledge to address information gaps, but much of which has not translated to adoptable products to increase reproduction efficiency on farms. **Finding 22:** Of all of the extension products delivered since inception of the SRRIP, the Lifetime Ewe Management program has had the most influence on sheep reproduction, impacting the management of around 6 million ewes in the past 6 years. However, over recent years the impact of the program on delivering producer gains in reproduction and ewe mortality has declined.	
Achievement of Sheep Reproduction Strategic Objectives	
Finding 23: The average annual national rate of gain in marking rates during the SRRIP delivery period is likely to have been between 1.0% and 1.4% for Merino lambs and between 0.6% and 1.7% for all other lambs. **Finding 24:** The SRRIP target of a 2% average annual increase in national lamb marking rate over the five-year investment period has not been met. The average rate of gain in marking rates during	

Findings	Recommendations
the SRRIP delivery period is likely to have been between 0.6% and 1.5% depending on the data source. This rate of gain is highly likely to have been negatively influenced by below average seasonal conditions over the SRRIP implementation period. **Finding 25:** Seasonal variation has a considerable impact on ewe reproduction rate, particularly for Merino enterprises, which makes it difficult to accurately assess the impact of investment in RD&E on national sheep reproduction outcomes.	**Recommendation 11:** Given that climate variability is likely to increase in the future, MLA and AWI to consider investigating methods for modelling the impact of season on sheep reproduction rate in an effort to account for at least some of the seasonal influences on measured reproduction outcomes. This information may also assist with communication of efforts to improve animal welfare outcomes with consumers and the challenges associated with increasing lamb survival on farms.
Product Impact Assessment	
Finding 26: The overall economic assessment of all projects in Category 1 (the project created or contributed to an existing or new output (product) with directly attributable adoption outcomes and adoption related productivity impacts) returned a net present value to industry of $93.40 million with a benefit: cost ratio of 5.2 and an internal rate of return of 39%. With a 20% higher rate of productivity gain and a 20% higher value of additional lambs weaned, RD&E investment returned a NPV of $197.84 million with a B:C ratio of 9.9, and with a 20% lower rate of productivity gain and a 20% lower value of additional lambs weaned, the NPV was $19.21 million with a B:C ratio of 1.9.	
Key Gaps in Sheep Reproduction RD&E	
Finding 27: It was the general view of stakeholders that research to date has provided answers to a large number of sheep reproduction issues, however that knowledge has not been well applied and adapted to different systems and zones to facilitate broad industry adoption. **Finding 28:** Feedback from some stakeholders suggested that the project funding model is overly reliant on priorities identified by SALRC/WALRC without sufficient consideration for 'what they don't know'. It was also considered by many that investment	**Recommendation 12:** Establish and maintain a national database of key performance indicator data for monitoring changes in sheep reproduction efficiency by: • Investing in the adaption of one national data collection process to enable reporting against all key statistics for tracking progress against sheep reproduction strategic objectives; • Developing a process for ensuring that all extension/adoption pathways establish and monitor key metrics for measuring engagement, adoption and impact that can be related to national data; and

Findings	Recommendations
priorities change too quickly, and that a longer-term approach to sheep reproduction R&D is required. **Finding 29:** Stakeholder feedback suggests that consultants who work directly with producer clients are an underutilised resource in the R&D process and that there is an opportunity to increase their involvement in the generation of research ideas, 'ground truthing' research ideas and in modifying and adapting adoption products and extension messages for more successful and broader industry application. **Finding 30:** It appears that R&D into sheep reproduction has been overly focussed on identifying and filling knowledge gaps rather than clearly defining problems at the farm level that need to be solved, and identifying what the best opportunities are for practically (and profitably) solving those issues. **Finding 31:** Stakeholders identified a range of current gaps in sheep reproduction extension in the following key areas: • Producer awareness of R&D outcomes and of available extension programs and activities; • Effective producer engagement to facilitate participation in extension programs and activities; • Capacity and capability of service providers to extend sheep reproduction messages; • Adoption of best practice management strategies for sheep reproduction by producers; • Translation of R&D outcomes to practical extension messages and adoptable changes on farms (research to practice); • Repeatability of best practice management outcomes on farms and producer dis-adoption; and • Extension products and tools.	• Ensuring that data used for reporting progress feeds into continuous improvement and evaluation processes so that results are informing delivery and investments are adjusted accordingly. **Recommendation 13:** Identify and segment the target audience for each adoption product to: • Define: - End users, e.g. commercial sheep producers, seedstock producers and their key characteristics, such as flock size, breed, enterprise mix and size, lambing time, participant age, geographical location. - Next users and their key characteristics, e.g.: ✓ Consultants/advisors – business, technical etc ✓ Trainers/educators ✓ Extension experts ✓ Service providers e.g. stock agents, wool brokers, pregnancy scanners, contractors (shearers, contract marking teams etc), vets, product company representatives, rural financial counsellors, bankers/loan brokers. ✓ Researchers ✓ Other members of the value chain e.g. wool processors, meat processors • Determine which segments are the target for each extension/adoption message/product and define: - Engagement targets - Adoption targets • Determine how best to engage each target audience and how that engagement will be monitored and evaluated. **Recommendation 14:** Increase the proportion of investment allocated to developing and extending research outcomes to enable more next and end users to benefit by: • Investing in a curated database to store all sheep reproduction RD&E project reports, including contact details for each project to enable follow up of outcomes. This database needs to be easily searchable and accessible to all stakeholders. Investment needs to cover maintenance and communication of contents widely to improve awareness across the industry.

Findings	Recommendations
	• Prioritising allocation of sufficient resources to ensure that an adoption pathway is established for all extension and adoption messages at the beginning of a project utilising input from extension specialists. • Reviewing R&D projects with adoptable outcomes by next users to determine extension/adoption messages, extension adoption pathway, target audiences (next users and end users) and what additional work is required to ensure that information/messages are: - Locally relevant - Economically viable - Applicable to the spectrum of different sheep business types i.e. Merino self-replacing, non-Merino terminal flocks etc, different lambing times, specialist versus mixed enterprise sheep farms, intensive versus extensive production systems. **Recommendation 15:** Investment be made in designing extension activities to achieve adoption by the target audiences, including next users, that aims to solve well defined on-farm problems: • Each R&D adoptable output (product) adoption pathway includes: - Extension method (awareness raising activities, training programs, workshops, demos, news articles, one to one or group, events etc.); - Definition of target audience (next and end users); and - Capacity and capability building of delivery network. • Adoption programs explore and define the required outcome from the end user's perspective before promoting the details of the program methodology: - What is the issue the program addresses? - How do producers determine whether it is an issue for them or not? - What is the impact of the issue on their farm and therefore is it worth solving, including prioritization of alternative changes, is it profitable to solve, and other benefits of solving the problem? • Invest in promotion and marketing of extension programs beyond word of mouth and traditional forms of advertising. This includes analysing participation data to inform approaches.

Findings	Recommendations
	Recommendation 16: MLA and AWI invest in the development of consistent MER frameworks to monitor performance of projects in addition to measuring impact and adoption that feeds into continuous improvement processes by: • Investing in the development and implementation of consistent MER for all extension projects/programs that reports on the success of the event/activity in terms of participation as well as adoption and impact of the project/program on farm. • Where possible, and particularly for larger projects, invest in processes to collect and validate impact data from producers over multiple seasons to more accurately assess long term impact. • Project/program evaluations be conducted by independent providers outside of project/program development and delivery activities. • Sharing valuation results with all project stakeholders including delivery staff, participants and other interested stakeholders. The aim is to: - Inform deliverers and participants of project achievements and shortcomings and provide feedback/validate their input (and may contribute to increased accuracy of evaluation data collected and results) and to demonstrate progress made. - Provide stories and data to further promote projects to other potential next users/end users and target audiences. - Justify investment of levies to producers by highlighting achievements.
Industry Collaboration on Sheep Reproduction RD&E	
Finding 32: Since commencement of the SRRIP, only 8% of all industry investment (and 10% of all projects) has involved collaboration between MLA and AWI, supporting stakeholder feedback suggesting that there is an opportunity for greater collaboration between MLA and AWI in the future. **Finding 33:** Considerable informal collaboration occurs via communication on a regular basis between MLA and AWI sheep reproduction management personnel to share information and ideas, to identify opportunities for potential project collaborations and to reduce the potential for duplication of research and extension efforts.	

Findings	Recommendations
Finding 34: Stakeholder feedback indicates a need for greater sharing of information regarding the status of what R&D is being undertaken across industry, regardless of funding source.	**Recommendation 17:** MLA and AWI to engage with research providers to investigate opportunities for provision of a centralised source of information on the status of sheep reproduction R&D regardless of funding source.
Finding 35: Stakeholder feedback indicates concern that a disproportionate amount of MLA and AWI sheep reproduction R&D funding is provided to a relatively small proportion of delivery organisations and individuals which limits the potential for maintaining and building R&D capacity and capability and increases risk.	**Recommendation 18:** MLA and AWI to review the potential for increasing the breadth of engagement with service delivery providers with the objective of ensuring that all relevant sectors are engaged, and to ensure the sustainability of capacity and capability within and across organisations involved in sheep reproduction R&D delivery.
Finding 36: Only five non-producer commercial businesses have been involved in delivery of sheep reproduction RD&E in 8% of projects since mid-2012, and there have only been three international organisations involved in project delivery over the same period of time. Stakeholder feedback indicates that there is an opportunity to increase engagement with both the commercial sector and international R&D providers to add value to sheep reproduction outcomes in Australia, and also with the education sector (secondary and tertiary) to engage with and influence the next generation of producers as early as possible.	**Recommendation 19:** MLA and AWI to actively identify and explore potential opportunities to engage more with the education sector (secondary and tertiary) to establish a relationship with and influence the next generation of producers as early as possible, and with commercial enterprises and international RD&E providers to partner with for sheep reproduction RD&E. **Recommendation 20:** MLA and AWI to identify and explore potential opportunities for collaboration with organisations and programs with environmental objectives, such as Landcare, CMAs, LWA and corporate businesses, in areas of sheep reproduction RD&E where environmental benefits can be demonstrated (e.g. increasing lamb survival and increasing reproductive efficiency of ewe lambs to decrease the carbon footprint per unit of product output).
Finding 37: There may be opportunities for attracting funding for sheep reproduction RD&E from environmental funding sources where RD&E outcomes that contribute to increasing environmental stewardship from sheep production systems can be demonstrated. **Finding 38:** There is an opportunity to minimise the financial costs and the additional time associated with achieving collaboration while maximising the utility of project outcomes for producers by: • Simplifying the process of project contracting between RDCs; and • Clarifying the objectives of IP and simplifying the process of determining IP arrangements.	**Recommendation 21:** MLA and AWI to establish agreed processes and principles for project management and IP arrangements for all projects delivered as part of the National Sheep Reproduction RD&E Investment Plan: • MLA and AWI to develop a consistent framework for defining terms and conditions for co-funded project investments as opposed to terms and conditions being developed and agreed to on a project by project basis. This may involve differentiating the process required depending on the type of investment, particularly where project outcomes involve commercialisation of a product or process compared to more knowledge-based project outcomes. • MLA and AWI to develop a set of key principles around the objectives of IP arrangements for project investments, to communicate these principles to funding partners and utilise them to

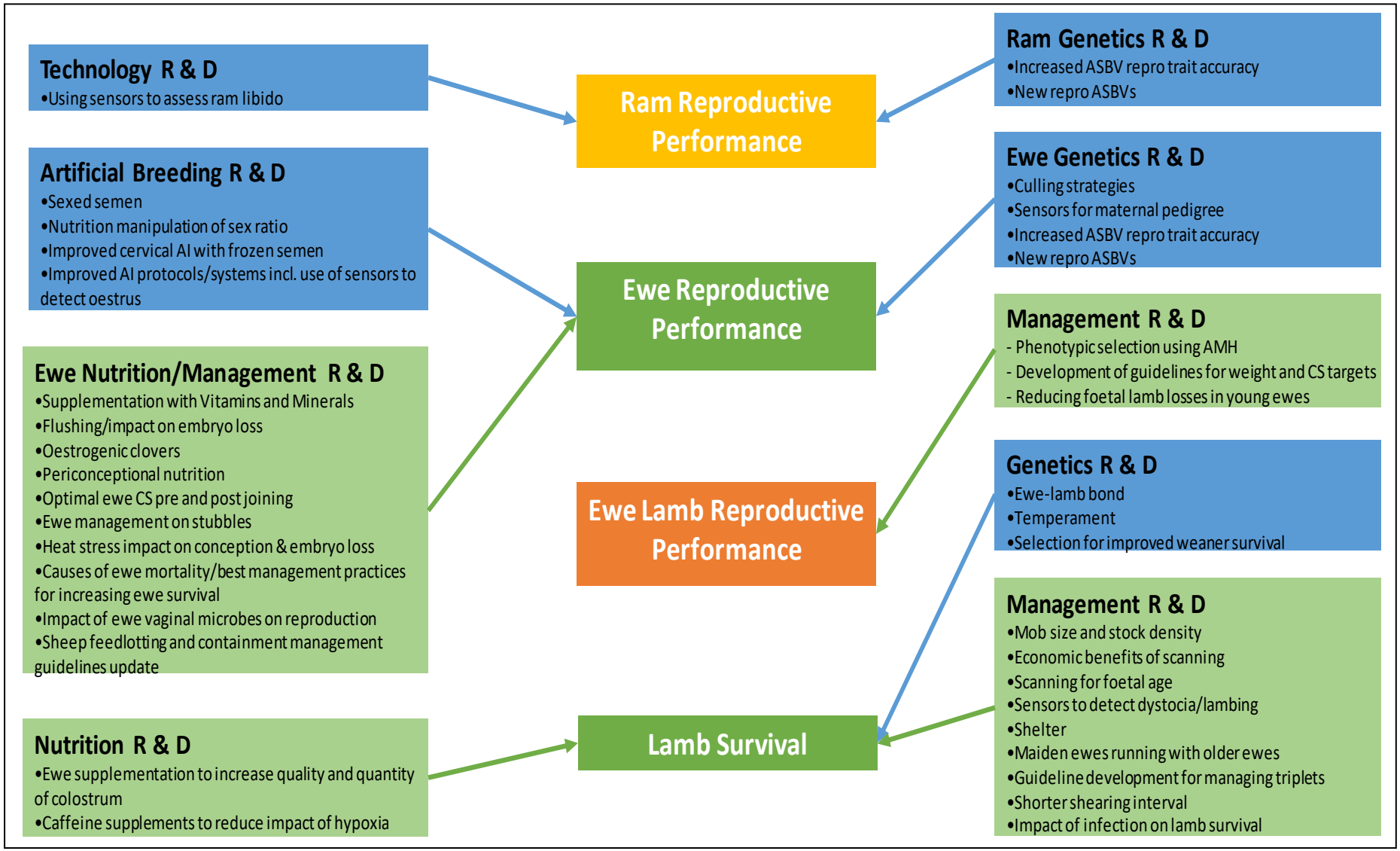
Findings	Recommendations
Finding 39: To facilitate more effective collaboration in the future there is a need to further incentivise service providers to collaborate with one another and with MLA and AWI, and to create a more strategic approach to decision making by MLA and AWI around co-funding of sheep reproduction projects.	guide development of IP arrangements at the project level. Suggested guiding principles could include: - IP arrangements should enable maximum utility of project outcomes for industry; - Delivery partners who do not provide funding to the project (either in-kind or cash) require a simple licensing agreement to utilise any IP generated from the project which is not publicly available beyond the terms of the project contract; - IP arrangements should ensure fair treatment of all funding partners in division of ownership of IP generated by project activities; and - IP arrangements should limit background and third-party IP to the minimum required for the project to simplify contracting processes. **Recommendation 22:** Increase the potential benefits from collaboration by increasing the incentive for industry partners to co-invest and share ideas, and provide a more structured framework for decision making around collaboration at a strategic level by: • Establishing large programs of work which extend over the period of the SRRIP and which align with the priorities identified in the SRRIP; • Identifying strategic partners who are willing and able to commit co-funding for each program area under agreed arrangements (via the Strategic Sheep Reproduction Partnership process currently in motion) to deliver required outcomes according to SRRIP KPIs; • Engage with relevant strategic partners to develop projects to address the key priority areas within each program; • Allocate approved project delivery activities within each program to strategic partners according to project requirements, co-funding committed and availability of relevant skills, knowledge, infrastructure and equipment within partner organisations. The emphasis should be on collaboration where this creates benefits, but also involve a willingness to make strategic decisions not to collaborate in instances where it is not considered cost effective to do so; • Where required, engage service providers outside of the strategic partnership where additional skills, knowledge or experience for achievement of project outcomes are considered to be necessary; • In addition to commissioned projects developed to align with achievement of SRRIP objectives, a portion of total available funding be committed to an open-call process for projects to facilitate generation of new ideas and research directions; and

Findings	Recommendations
	• At the RDC level, based on available funding, MLA and AWI identify their priority areas for funding allocation, and where these areas cross-over, co-funding arrangements are implemented. This may be at a program investment level, or if more delineation of investment areas is required, at the project level.

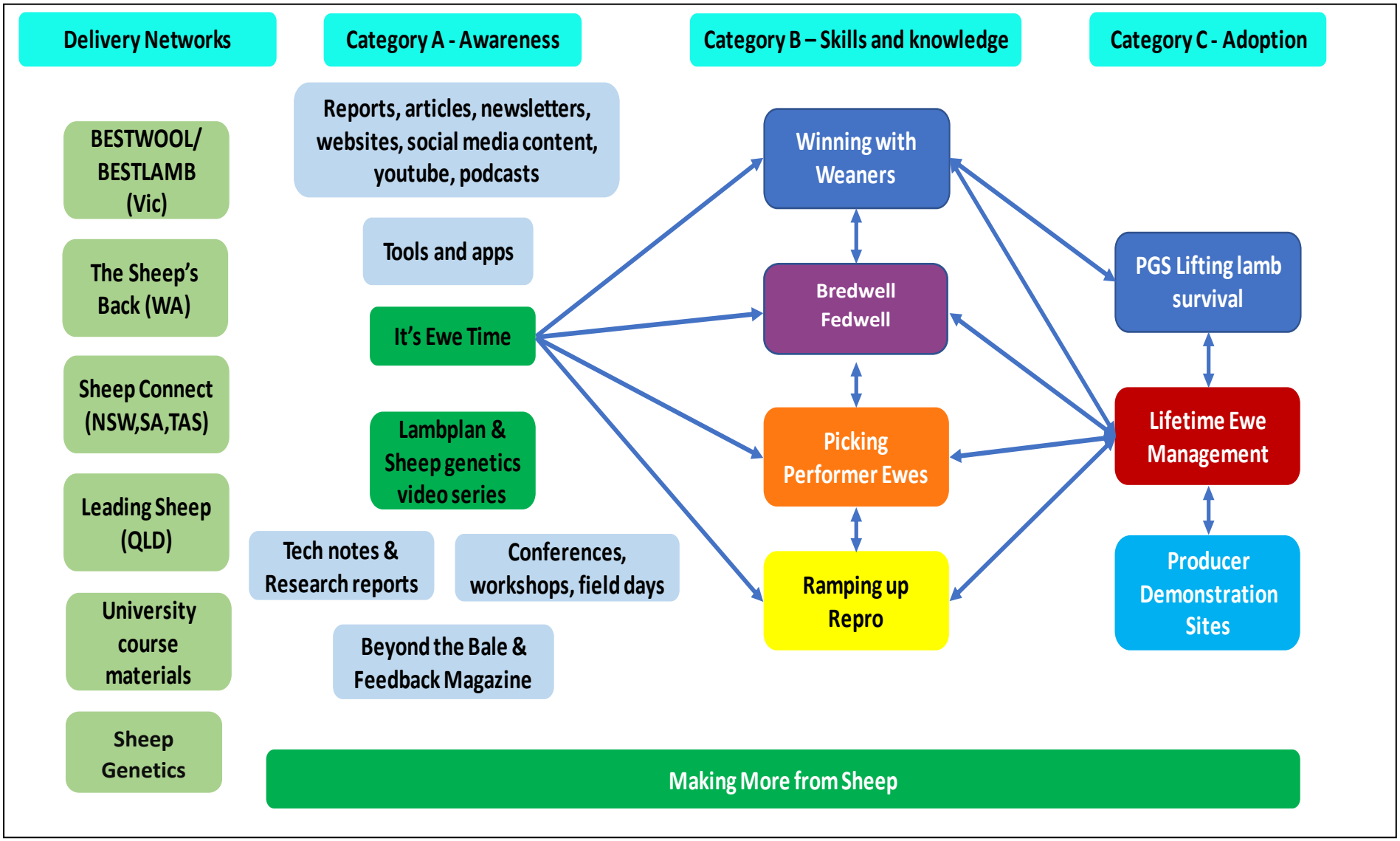
Appendix B - National Sheep Reproduction Plan Investment Framework (2012-2017)

Investment Pillar	Aim	Project Cost ($m)				Project Investment
		Strategic Research	Applied Research	Development & Extension	Total	
Conception and Early Embryo Mortality	**To improve conception rates by;** I. Researching, demonstrating and implementing nutritional strategies that improve ovulation rates, ewe condition at mating, and conception rates, and **II.** Quantifying the loss of embryos in early pregnancy (pre and post implantation), investigating and extending ways to minimize embryo loss.	**0.1**	**0.8**	**0.4**	**1.3**	**5%**
Ewe and Lamb Survival	**To improve ewe and lamb survival by;** I. Developing and extending recommended nutrition profiles for pregnancy and lactation for adult Merino, crossbred and Dorper ewes, II. Research, demonstrate and extend tactical management strategies that improve ewe and lamb survival, particularly twin lambs, and **III.** Researching and implementing innovative extension strategies that create widespread industry impact.	**1.4**	**4.7**	**8.1**	**14.2**	**58%**
Early Reproductive Success and Weaner Performance	**To improve early reproduction success in maiden ewes and weaner performance by;** I. Quantifying current industry performance of maiden ewes lambing at either one or two years in various breed types, II. Developing and extending best practice guidelines for the nutrition and management of maiden ewes, and **III.** Evaluating the impacts of lambing at 12-15 months on lifetime performance.	**1.0**	**2.2**	**1.7**	**4.9**	**20%**
Genetics and Biological Mechanisms	**To improve reproductive efficiency by;** I. Defining biological mechanisms that drive reproduction and interactions with the production environment, II. Increasing the potential for genetic gain in reproduction by improving the genetic parameters, accuracy of data collection and genetic analysis, and III. Developing and extending nutrition and genetic strategies that increase reproduction rates.	**2.5**	**0.9**	**0.9**	**4.3**	**17%**
Investment split by RD&E (%)		**20%**	**35%**	**45%**		**100%**

Appendix C – Key Areas of Sheep Reproduction RD&E



Key Areas of Sheep Reproduction Extension



Appendix D – Stakeholder Engagement

Stakeholder Participant Organisations and Sectors

Organisation/Sector
Peak Councils
Sheep Producers Australia
WoolProducers Australia
State Farmer Organisations
AgForce Queensland
NSW Farmers Association
Victorian Farmers Federation
Tasmanian Farmers and Graziers Association
Livestock SA
WAFarmers
Producer Group/Producer
SALRC
WALRC
Birchip Cropping Group
ASHEEP
Producer x 50 (1 phone interview, 49 online surveys)
Supply Chain Representatives
Wool broker x1
Meat processor x1
Universities
University of Western Australia
Murdoch University
University of Adelaide
University of Melbourne
University of Sydney
Charles Sturt University
University of New England
Central Queensland University
University of Tasmania
Massey University (NZ)
Other Research Organisations
CSIRO
AGBU
AgResearch NZ
SARDI
State Government
NSW Department of Primary Industries
Victorian Department of Jobs, Precincts and Regions
Primary Industries and Regions SA-Rural Solutions SA
Department of Primary Industries and Regional Development WA
Extension Specialist/Consultant
Livestock Logic
Dynamic Ag
JT AgriSource
Mackinnon Group

Organisation/Sector
AgriPartner Consulting
Icon Ag
Macquarie Franklin
Rural Analytics
Farming Systems
neXtgen Agri
Sheep Connect NSW
Sheep Connect TAS
Leading Sheep QLD

Appendix E – Strategic Alignment

Alignment of SRRIP RD&E Pillars with Key Industry Strategies and Programs

SRRIP Pillar	Alignment with Industry Strategy/Program				
	MISP	SISP	WIRNS	NAWRDE	Sheep CRC
Conception & Early Embryo Mortality	**Pillar 1 - Consumer and Community Support:** ✓ Continuous improvement of animal welfare ✓ Adapting to climate variability **Pillar 4 - Productivity and Profitability:** ✓ Decision support to improve farming businesses ✓ Increasing livestock productivity through new research	**Theme 1 - Wellbeing of the animals in our care:** ✓ Continuous improvement of sheep health & wellbeing **Theme 2 - Stewardship of environmental resources:** ✓ Adapting to climate variability **Theme 8 - Production efficiency in farms and in intensive finishing systems:** ✓ Systems support to improve the farm businesses ✓ Increasing livestock productivity through new research	**Program 1 - Increase Productivity:** ✓ Running the right sheep for the right enterprise through breeding decisions ✓ Increased reproductive performance of Merinos ✓ **Program 2** - Optimise adoption **Program 4 - Manage risks** ✓ Animal welfare ✓ Climate variability	**Theme 2 - Pain assessment & management:** ✓ Improvement/replacement of aversive practices	✓ **Program 1:** Enhanced sheep wellbeing and productivity
Ewe & Lamb Survival	**Pillar 1 - Consumer and Community Support:** ✓ Continuous improvement of animal welfare ✓ Adapting to climate variability ✓ Minimising industry impact on the environment **Pillar 4 - Productivity and Profitability:** ✓ Decision support to improve farming businesses ✓ Increasing livestock productivity through new research	**Theme 1 - Wellbeing of the animals in our care:** ✓ Continuous improvement of sheep health & wellbeing **Theme 2 - Stewardship of environmental resources:** ✓ Adapting to climate variability ✓ Minimising sheep industry impact on the environment **Theme 8 - Production efficiency in farms and in intensive finishing systems:** ✓ Systems support to improve the farm businesses ✓ Increasing livestock productivity through new research	**Program 1 - Increase Productivity:** ✓ Increased reproductive performance of Merinos ✓ Increase ewe, weaner and lamb survival ✓ **Program 2** - Optimise adoption **Program 4 - Manage risks** ✓ Animal welfare ✓ Climate variability	**Theme 1 - Animal welfare assessment:** ✓ Minimisation of negative AW states. ✓ Optimise positive AW states. ✓ **Theme 6** - Education, training and extension	✓ **Program 1:** Enhanced sheep wellbeing and productivity

SRRIP Pillar	Alignment with Industry Strategy/Program				
	MISP	SISP	WIRNS	NAWRDE	Sheep CRC
Early Reproductive Success and Weaner Performance	**Pillar 1 - Consumer and Community Support:** ✓ Continuous improvement of animal welfare ✓ Minimising industry impact on the environment **Pillar 4 - Productivity and Profitability:** ✓ Decision support to improve farming businesses ✓ Increasing livestock productivity through new research	**Theme 1 - Wellbeing of the animals in our care:** ✓ Continuous improvement of sheep health & wellbeing **Theme 2 - Stewardship of environmental resources:** ✓ Minimising sheep industry impact on the environment **Theme 8 - Production efficiency in farms and in intensive finishing systems:** ✓ Systems support to improve the farm businesses ✓ Increasing livestock productivity through new research	**Program 1 - Increase Productivity:** ✓ Running the right sheep for the right enterprise through breeding decisions ✓ Increased reproductive performance of Merinos ✓ Increase ewe, weaner and lamb survival ✓ **Program 2** - Optimise adoption **Program 4 - Manage risks** ✓ Animal welfare	**Theme 1 - Animal welfare assessment:** ✓ Minimisation of negative AW states. ✓ Optimise positive AW states. ✓ **Theme 6** - Education, training and extension	✓ **Program 1:** Enhanced sheep wellbeing and productivity
Genetics and Biological Mechanisms	**Pillar 1- Consumer and Community Support:** ✓ Continuous improvement of animal welfare ✓ Minimising industry impact on the environment **Pillar 4 - Productivity and Profitability:** ✓ Decision support to improve farming businesses ✓ Increasing livestock productivity through new research	**Theme 1 - Wellbeing of the animals in our care:** ✓ Continuous improvement of sheep health & wellbeing **Theme 2 - Stewardship of environmental resources:** ✓ Minimising sheep industry impact on the environment **Theme 8 - Production efficiency in farms and in intensive finishing systems:** ✓ Systems support to improve the farm businesses ✓ Increasing livestock productivity through new research	**Program 1 - Increase Productivity:** ✓ Running the right sheep for the right enterprise through breeding decisions ✓ Increased reproductive performance of Merinos ✓ Increase ewe, weaner and lamb survival ✓ **Program 2** - Optimise adoption **Program 4 - Manage risks** ✓ Animal welfare	**Theme 1 - Animal welfare assessment:** ✓ Minimisation of negative AW states. ✓ Optimise positive AW states. ✓ **Theme 6** - Education, training and extension	✓ **Program 1:** Enhanced sheep wellbeing and productivity ✓ **Program 3:** Faster, affordable genetic gain
Percentage of projects aligning with strategy/program	100%	100%	93%	57%	100%

Appendix F – Lamb Survival Data

Range of Reported National and International Lamb Survival Data by Birth Type

Country	Breeds	Method*	Reported Range in Lamb Survival (%)			
			Average	Single	Twin	Triplet
Extensive Production Systems						
Australia[26]	Merino only	LSOS LSFS	76.5 81.1	83.4 89.0	56.2 66.9	n.a.
	Merino/Merino x/non-Merino	LSFS	74.7-77.0	83.5-90.0	68.5-72.0	n.a.
New Zealand[27]	Various (predominantly non-merino breeds)	LSFS LSLB	78.3 88.0	88.3 83.0-92.6	79.4 73.0-87.0	57.4 71.0-75.2
South Africa[28]	Merino/Dohne/SAMM	LSLB	78.0-85.1	88.2-91.6	81.3-87.2	50.0-63.7
	Dorper	LSLBA	88.0	n.a.	n.a.	n.a.
France[29]	Merino	LS60	86.7	n.a.	n.a.	n.a.
	Romane	LS60	80.4	91.1	85.9	76.7
United Kingdom[30]	Scottish Blackface	LSFS	82.2-86.2	79.6-87.5	83.8-85.1	77.3-77.8
	Lleyn	LSFS	81.0	83.9	84.6	70.3
Intensive Production Systems						
Australia[31]	Meat breeds >80% indoor lambing	LSFS	87.0-94.0	90.0-96.5	85.0-96.5	74.5-86.5
France[32]	Various meat breeds	LS60	83.9-90.3	88.2-93.1	85.6-93.2	74.7-93.2
United Kingdom[33]	Various breeds >80% indoor lambing	LSLB	90.0	n.a.	n.a.	n.a.
Ireland[34]	Various meat breeds	LSLB	n.a.	88.2	90.1	78.9
Norway[35]	Meat breeds	LS14	92.2-93.0	93.0-94.0	93.0-93.5	85.3-86.9

*LSFS- lambs surviving to marking of foetuses scanned in mid-pregnancy. LSOS – lambs surviving to weaning of ova shed. LSLB – lambs surviving to weaning of lambs born (alive and dead). LSLBA – lambs surviving to weaning of lambs born alive. LS60 - lambs surviving to 60 days of age of lambs born (alive and dead). LS14 – lambs surviving to 14 days of age.

[26] Kelly (1992); Kleeman and Walker (2005); Fowler (2007); and Allworth *et al*. (2017).
[27] Dalton *et al.* (1980); Nicholl *et al.* (1999); Kerslake *et al.* (2005); and Everett-Hincks *et al.* (2014).
[28] Cloete *et al*. (1999); Zishiri *et al*. (2013); and Cloete and Cloete (2015)
[29] INRA experimental farms – unpublished F. Brien pers. comm.
[30] Scotland Rural University College research farms – unpublished F. Brien pers. comm.
[31] Long term average farm data for approx. 600 ewes – unpublished S. Beattie (Vic) pers. comm. This is a very intensively managed lambing system with 24 hour monitoring of ewes which are penned individually with stringent hygiene practices. The business also focusses strongly on genetics to decrease dystocia via a focus on reducing GL which has manifested in higher lamb survival over the past 5 years (a decrease of 1.5 days av. GL has been achieved over the past 5 years); Long term average farm data for approx. 1,000 ewes – unpublished D. Bradford (WA) pers. comm. Lambing system involves ewes penned with 2-3 per pen and 14 hour monitoring.
[32] INRA experimental farm – unpublished; Gautier and Corbiere (2013); unpublished F. Brien pers. comm.
[33] Binns *et al*. (2002)
[34] Keady *et al*. (2018)
[35] Holmoy and Waage (2015)

Appendix G – Example Regional Data Analysis

ABARES regional data analysis for Merino enterprises (est.) in Victoria

Region	Change in Average Marking Rate between the two periods* (% points)	Most recent 4 Year Average Marking Rate (2014/15 to 2017/18)	Percentage of all ewes joined to Merino Rams in Victoria in 2017/18
Mallee	-12%	81%	2%
Wimmera	-2%	78%	16%
East Gippsland	4%	75%	2%
North East	4%	82%	1%
Goulburn Broken	9%	89%	1 %
North Central	16%	87%	20%
West Gippsland	17%	81%	2%
Glenelg Hopkins	24%	87%	29%
Corangamite	25%	90%	16%

* Percentage change in average marking rate between 2010/11 to 2013/14 and 2014/15 to 2017/18.

ABARES regional data analysis for all other sheep enterprises in Victoria

Region	Change in Average Marking Rate between the two periods* (% points)	Most recent 4 Year Average Marking Rate (2014/15 to 2017/18)	Percentage of all ewes joined to non-Merino Rams in Victoria in 2017/18
West Gippsland	3%	102%	3%
Corangamite	5%	106%	10%
Glenelg Hopkins	6%	110%	46%
North Central	6%	106%	14%
Wimmera	7%	106%	12%
East Gippsland	8%	108%	1%
North East	9%	101%	2%
Goulburn Broken	10%	119%	9%
Mallee	14%	105%	3%

* Percentage change in average marking rate between 2010/11 to 2013/14 and 2014/15 to 2017/18.