

Breech Flystrike Prevention Genetic R&D Review

Independent review of Australian Wool Innovation's Breech Flystrike Prevention Genetic Research, Development and Extension Program, June 2019

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Executive Summary

The 2019 review of the genetic components of AWI's Breech Strike Research Development and Extension program was conducted by reference to research reports, extension materials and meeting catalogues and at a meeting with Australian Veterinary Association and AWI representatives in April 2019. The major breech flystrike selection flock experiments, commenced in 2005 at Mt Barker in Western Australia and at Armidale in New South Wales, have now been completed. The key findings are that genetic gains can be made in reducing susceptibility to breech flystrike by selecting sheep on scores for breech wrinkle, breech cover, dag and urine stain and that these gains can be made simultaneously with improvement in the major production traits, fleece weight and fibre diameter. A subsequent study quantified the genetic gains possible by different selection strategies across different Merino sheep types and production environments and will help guide breeding strategies. A review of the predisposing factors for breech strike and the response of flies to sheep odours has been recently completed and recommendations have been provided for the future direction of research on breech strike risk factors, including the utility of retaining ewes from the Mt Barker and Armidale breech strike selection flocks as a genetic resource for use in future studies.

The use of gene markers and genomic indices for selection offers major potential advantages by enabling selection in the absence of environmental challenge and at younger ages. Recently completed analysis, which included all of the available genetic material, did not find gene markers of major effect. However, the work indicated that genomic indexes, incorporating a number of genes, could make a valuable contribution to improving the accuracy of breeding values. Sequencing the sheep blowfly genome has been a further major advance and with the aid of AWI funding, research is currently underway to exploit this knowledge towards the development of new, rationally designed blowfly insecticides, flystrike vaccines and other novel methods directly targeting fly populations. This is frontier basic research that directly targets the genetic code of the sheep blowfly and has major potential impact for the wool industry. Continuing work in this area is strongly supported.

Australian Sheep Breeding Values for breech wrinkle, breech cover and dag scores, implemented since 2009 as part of the MERINOSELECT service (provided by Sheep Genetics) are now available for use by ram breeders and wool producers on 20-30% of recorded animals. The scoring systems developed for flystrike indicator characters also assist selection for resistance on properties where traditional breeding methods are used.

A considerable extension effort has been made to make the research outcomes available to wool producers and facilitate its practical usefulness through grower training days and workshops and the provision of updated information via the AWI 'Beyond the Bale' magazine and the FlyBoss, Sheep Genetics and AWI websites. FlyBoss has added a new section "Ten steps to a ceased-mulesing flock" 'and a report of the project 'Rate of Genetic Gain in Reducing Breech Flystrike' which provides guidance as to rates of gain in flystrike resistance that can be expected under commercial conditions, has been made available on the AWI website. We commend the considerable effort to date to develop improved methods for selecting sheep for breech strike resistance, adapting these to practical recommendations and in ensuring the information is readily available to wool producers, ram breeders and other industry stakeholders. However, further extension effort to encourage increased recording of breech traits and the development of selection index options that incorporate them in MERINOSELECT is required. Detailed recommendations from the 2019 review are provided in the body of the report and a summary of progress is contained in a table in the appendix, which follows the framework of the Research, Development and Extension matrix used by AWI.

Breeding and selection research

To identify the most effective breeding strategies AWI, in partnership with wool producers, national and State research providers and other industry stakeholders has undertaken a comprehensive research, development and extension program to develop and advance the implementation of optimal breeding programs for breech strike resistance. General consensus within the wool industry is that breeding more resistant sheep will be critical and, over the longer term, the most important and sustainable tool to control breech strike in non-mulesed flocks.

In 2005, AWI commenced a major research project (EC940 Breeding for Breech Strike Resistance) conducted in two major sheep production zones, the summer rainfall zone of New South Wales and the Mediterranean climate of south-western Western Australia. These two areas have dissimilar environments and different management systems and are representative of a significant proportion of sheep production in Australia. Final reports of Phase 1 of the project were provided in 2010. Phase 1 confirmed the presence of significant genetic variability amongst sheep in susceptibility to breech strike, identified breech wrinkle, dags, breech wool cover and urine stain as indirect characters for flystrike resistance and provided preliminary genetic parameters for flystrike resistance. The scoring systems developed for these indicator characters have found industry acceptance and are aiding selection for breech strike resistance in both performance and traditional selection programs. Phase 2, conducted from 2010 to 2016, collected further data and significantly improved the precision of genetic parameter estimates for resistance to breech flystrike and its relationship with other traits. In addition, in Phase 2, management of the WA selection flock was modified to include a winter crutch, a commonly used management practice in Mediterranean environments. This reduced the overwhelming effect of dags seen in Phase 1 at the WA site and provided valuable insight into the relative value of other indirect traits and rates of gain in flystrike resistance that can be made under both crutched and un-crutched management systems. A substantial amount of extra data was contributed to the Sheep Genetics database, significantly adding to the accuracy and precision of Australian Sheep Breeding Values (ASBVs) for flystrike resistance available to sheep producers. One of the findings from this research was that despite the identification of key factors responsible for differences in sheep susceptibility to breech strike

(breach wrinkle, dags, breach cover and urine stain), a proportion of the total variation in strike incidence remained unexplained, particularly for males.

Studies with sniffer dogs indicated that they could be trained to accurately distinguish wool samples from resistant and susceptible sheep. AWI Project ON-00169 (Breeding Breach Flystrike Resistance), aimed at identifying further factors influencing variation in susceptibility to flystrike commenced in 2012. Early studies examining differences in odour, fleece microflora and responses elicited from fly antennae were extremely encouraging, but some, more recent aspects have been more equivocal. A review of the outcomes from the project and the results of other research more generally on breach strike risk factors has been recently completed (AWI Project ON-00510 Blowfly and Sheep Attraction Review). Among key findings from this review, it was concluded that although odour is involved at a number of stages in the development of breach flystrike, it was unlikely that odour components could provide an accurate and practically useful criterion for selecting for breach strike resistance. However, bacterial odours and other volatiles associated with predisposing causes of flystrike, such as urine and faecal staining, are critical to the initiation of strike and methods that interfere with the perception of odour by the flies, for example by targeting olfactory genes or processes, or the identification of strongly repellent molecules, may lead to novel control approaches.

The amount of variation in breach strike susceptibility not explained by the major indicator characters will be key to a consideration of the need for new or better indirect selection criteria. There is little unexplained variation in some data sets, for example in crutched ewes in WA where only 9.4% of the variation remains unexplained and where dags and skin wrinkles explain most of the phenotypic variation. This differs from the unmulesed, uncrutched flocks in WA and crutched sheep in NSW where approximately 50% of the variation remains unexplained. There is a need for a 'harmonised analysis' of the WA and NSW data followed by careful consideration of what percent of the unexplained phenotypic variation is environmental in origin, what percent is likely to be genetic, what fixed effects have been taken into account in different analyses and what likelihood there is that future research can find new indicator characters that significantly increase the accuracy of selection for flystrike resistance.

Encouragement of much more widespread phenotyping for flystrike traits is required to provide more robust and widely applicable estimates in MERINOSELECT. This is particularly so for urine stain, which currently does not have a breeding value available in MERINOSELECT, and for scouring/dags. To this end there is a need to facilitate easier methods of measurement of 'difficult' traits such as urine stain and scouring/dags. This could be easier methods of assessing them, or perhaps indirect methods of estimating urine stain/risk of urine stain. The recording of alternative more readily measured estimates for the main flystrike traits e.g. faecal consistency for scouring, face cover for bare area, neck and body wrinkle for breach wrinkle for recording in MERINOSELECT and presentation of ASBVs for these traits should also be considered. Progeny testing of elite sires directly for breach strike incidence could provide an avenue for increased accuracy and maximising industry genetic gain in flystrike resistance. There is also a need to facilitate practical 'useability' of breach strike traits in MERINOSELECT for sheep breeders. Breeding indices that incorporate breach strike resistance while at the same time maximise genetic gains for other traits are needed. Optimal incorporation of breach strike resistance in breeding indices will require the derivation of an economic value(s) for breach strike resistance.

It is well established that bacterial growth is important at various stages in the development of bodystrike; for example in providing odour cues for attraction and oviposition, causing skin scalding and extravasation which provides protein for the development of 1st instar larvae and by providing a focus for skin invasion by newly hatched blowfly maggots. There has been much less study of the importance of the breech fleece microbiome and interactions with urine stain and scouring, or of the importance of bacteria in the development of breech strike. There is indication that bacterial growth could be similarly important in determining breech strike susceptibility. Studies of the fleece/skin microbiome and its changes when conditions become suitable for flystrike may yield additional important information towards the development of new approaches to control, for example vaccination against key bacteria, blocking bacterial odours, the use of bactericides or biological methods to control critical bacteria.

The two breech strike flocks provide a source of very accurately pedigreed and phenotyped animals and are in completely different environments with different flystrike profiles. The depth of phenotyping for flystrike incidence in the flystrike selection lines in WA (now at Katanning) and NSW (Chiswick) makes these flocks an important core resource for genomic studies, a prime resource for identifying and testing new indicator characters and valuable for obtaining more precise genetic parameters for the development of more accurate selection and breeding programs. The flocks will also be an important resource for research in other areas, for example investigating the role of bacteria and other microbes in susceptibility, testing the efficacy of new vaccine technologies and resistant phenotypes, and the future development of welfare indices and breeding values incorporating breech strike resistance.

Genomic breeding values and indexes

Directly assessing the genes responsible for variation in flystrike susceptibility is a further means of increasing the accuracy of selection and rate of improvement in breech strike resistance and could provide an alternative to the use of traits such as dags and urine stain, which can be difficult to assess in practice. Gene markers and genomic breeding values offer advantages by enabling selection at younger ages and in the absence of environmental challenge, reducing the substantial labour input involved in scoring phenotypic characters, and potentially increasing rates of genetic gain in breech strike resistance. Project WP550 (Breech Flystrike Genomics) and recently completed Project ON-00515 (Genotyping of Breech Flystrike Resource) identified substantial numbers of genomic (SNP) markers for breech flystrike resistance and breech indicator traits for the sheep bred in Phase 1, and in Phase 1 and 2, respectively. However, both projects report that the sizes of the individual SNP effects were small and unlikely to be useful when used individually for selection. However, they could contribute to higher accuracy in estimating breeding values when included with other genes in a genomic index or when used in combination with more conventional phenotypic data. Difficulty in identifying individual genes or loci for factors determined by interactions of many genes, as is likely to be the case with flystrike susceptibility, is not uncommon. This has led to increasing use of genomic indexes incorporating many genes, which have generally given much higher levels of accuracy. These results lend support to the high priority recommendation from the recent Breech Strike Review Workshop (AWI Project ON-00510 Blowfly and Sheep Attraction Review) to ‘invest in a genomics reference flock towards the creation of genomic markers/indexes/breeding values for flystrike resistance’.

Sheep blowfly genetics

Updated mapping of the sheep blowfly genome (AWI Project ON-00373 Genetics of Blowfly Parasitism) identified some 12,933 protein coding genes, with more than 570 of them sheep blowfly specific and AWI Project ON-00570 (CRISPR Phase 3) is adapting the ground breaking new CRISPR/Cas9 gene editing technology for potential use in knocking out critical sheep blowfly genes. Significant progress has been achieved with successful deletion of the ‘Orco’ gene, which is important in odour detection, a critical step for the establishment of strikes by sheep blowflies. Given the large amount of transcriptome data being analysed, there are likely to be many other genes of interest that could be targeted in control programs, for example genes involved in the location of susceptible sheep by *L. cuprina*, dermal invasion by blowfly maggots, the initiation of strike and genes critical for the development and growth of blowfly larvae. This ground-breaking work offers exciting prospects for the future and research projects supported by AWI are now utilising the *L. cuprina* genome to develop blowfly specific insecticides (Project ON-00454 New Chemicals for Sheep Blowfly Control), vaccines (AWI Projects ON-00624 Informed Development of Flystrike Vaccine, and ON-00619 Vaccine for Control of Flystrike) and potentially, area-wide approaches directly targeting *L. cuprina* populations.

Grower, industry and domestic stakeholder extension, training and communications

Analysis of all data collected in Mediterranean and summer rainfall climates in Phases 1 and 2 of the breech strike resistance program has enabled translation of the research outcomes to optimal recommendations for wool producers and ram breeders. Australian Sheep Breeding Values (ASBVs) are available through the MERINOSELECT service for the principal indicators of breech strike resistance, breech wrinkle, breech cover and dag scores. Extensive submission of industry data has enabled ASBVs for breech wrinkle and breech cover to be issued with acceptable levels of accuracy and broad applicability to the range of Merino strains and types run in different parts of Australia. These ASBVs are facilitating the design of effective breeding programs for Merino breeders and commercial wool producers to improve breech strike resistance and increasing confidence that genetic improvement of sheep can provide the basis for wool producers to cease mulesing. The availability of ASBVs for dag score is also providing preliminary estimates for this trait for Merino types in areas where dag prevalence is high. However, management practices are designed to reduce expression of dags and urine stain, accurate assessment can be difficult and there is understandable industry resistance to allowing young sale rams and ewes to develop significant levels of dags so that scores can be accurately assessed. The creation of an ASBV for faecal consistency score would provide an alternative to breeders collecting dag score information in these situations and, potentially, in areas where dag prevalence is low. ASBVs are presently not available for urine stain for similar reasons and accurate assessment of urine score is even more difficult than for dags. Research Flocks and progeny testing sites run by the Australian Merino Sire Evaluation Association (AMSEA) are very important industry resources where dag and urine stain scores are currently being collected. Commercial growers and stud breeders should be encouraged to obtain dag and urine stain data from breeding stock where possible. Research flocks and sire evaluation sites could also be used to provide more data for these traits when the opportunity arises. Wrinkle scores on the neck and body are genetically correlated with those on the breech and could be used as indirect estimates for breech wrinkle where direct assessment of breech wrinkle is difficult. Further, AWI Project ON00524, has now provided wool producers with realistic assessments of the time it will take to breed increased resistance in different Merino

flock types to a point where ceasing mulesing is a realistic option. However, although ASBVs are available for breech traits from the MERINOSELECT website, they are not currently available as part of any index aimed at increasing flystrike resistance and have to be used independently. Incorporation of breech traits as part of formal index options, provided from the website, would greatly assist the adoption and optimal use of breech traits in breeding programs. The recently developed RamSelect mobile phone app has increased accessibility to sheep ASBVs and is an important advance for practical sheep selection. However, because flystrike resistance is not currently included in any formal index, this app currently has limited practical usefulness for strike resistance breeding programs.

A considerable effort has been made to make the results of research from the AWI Breech Strike Research and Development Program available to wool producers and facilitate their use in practice in both traditional and performance breeding flocks. Vehicles for this include regular Breech Strike Newsletters reporting outcomes from the WA and NSW sites during Phases 1 and 2 of the project, the AWI 'Beyond the Bale' magazine and the FlyBoss, Sheep Genetics and Australian Wool Innovation websites (www.wool.com). A notable addition in this reporting period is the report from Project ON-00524 Report, 'Rates of Genetic Gain in Reducing Breech Flystrike' now downloadable from the AWI Website which will help inform the choice of different approaches to breeding breech strike resistance. Communication activities to other wool industry stakeholders during the reporting period include the biennial Flystrike RD&E Update in July 2018, presenting the latest progress in the area of flystrike research to key stakeholders across all sectors of the wool industry, and the Animal Welfare Forum in December 2018, engaging with representatives of the peak Australian animal welfare organisations.

The FlyBoss website presents a dynamic and accessible platform for rapid dissemination of research outcomes and new information on best practice strategies and FlyBoss usage has continued to grow with user numbers increasing by 29% to 18,513 in 2016, 22% to 22,562 in 2017 and a further 37% to 30,918 in the latest year, 2018. The ParaBoss News e-newsletters are now sent to 3,447 subscribers, twice per month, with each newsletter containing a section on flystrike control. The ParaBoss Facebook page, started in mid-2016, has 1533 likes up 48% from last year, while the ParaBoss Technical Forum (a web forum for professional advisors) has 269 members up 79% from last year. Other innovations in FlyBoss in this reporting period include addition of the Transition to a Ceased-Mulesing Flock page and in particular, the section "Ten Steps to a Ceased-Mulesing Flock" together with an online learning module on breeding and selection for flystrike resistance. A new responsive version of FlyBoss, easily accessed from tablets and mobile phones, will be launched later in 2019 and will make FlyBoss easily accessible from field sites for purposes such as for accessing breech trait scores during sheep classing or making decisions about the application of flystrike treatments.

Concluding comments and recommendations

- The breech flystrike selection flocks have provided a critical source of accurately phenotyped animals for use in a number of facets of breech strike research and provide an important resource for future studies. Sheep from these flocks should be retained if possible and wool and genetic material should continue to be collected from all study animals for use in potential future research.
- The further recording of dag score in industry flocks and of urine score in areas of low dag prevalence should be encouraged. Where dag prevalence is low, the collection of faecal consistency scores and the development of a breeding value for the trait are supported.
- ASBVs for neck and body wrinkle scores should be made available for situations where breech scores are difficult to record.
- To facilitate more widespread adoption and efficient selection of sheep for lower susceptibility to breech strike and to improve genetic gains, there is a need to formally include breech strike resistance in breeding objectives for different environments and flock types, preferably as options available in MERINOSELECT, but also as customized breeding objectives for individual breeders.
- The provision of genetic trends for breech traits by Merino sheep type on the MERINOSELECT/Sheep Genetics website should be encouraged, as it would allow ram breeders, commercial wool producers and other wool industry stakeholders to more readily assess industry progress towards breeding sheep less prone to breech flystrike. The potential of progeny testing elite sires for estimation of more accurate ASBVs for flystrike resistance should also be considered.
- Analysis of the phenotypic data and tissue material collected during Phases 1 and 2 of the breech strike selection project suggests that the use of genomic indexes and genomic enhanced breeding values for breech strike resistance could significantly improve the ease and accuracy of selection and rates of gain in breech strike resistance. The establishment of a reference population to progress this work was recommended with high priority as an outcome of the recent Breech Flystrike Review Workshop
- Mapping of the sheep blowfly genome is an exciting achievement which, together with availability of the ground-breaking CAS/CRISPR gene editing technology, offers the possibility of directly targeting essential sheep blowfly genes and the development of innovative new controls for flystrike. New projects recently funded by AWI offering new possibilities for the future and facilitated by knowledge of the sheep blowfly genome include the development of flystrike vaccines and the design of new, sheep blowfly-specific insecticides.
- Research towards better methods of flystrike control has been accompanied by a comprehensive extension campaign to stakeholders and we congratulate the numerous organisations and individuals involved in the development and delivery of these programs. Extension designed to assist sheep owners make rapid genetic gains in breech strike resistance in both performance and traditionally bred flocks should continue to be a priority. Support of the excellent web-based information resources and tools and programs of meetings and forums to aid practical implementation will be critical to maximizing industry adoption. The recent publications ‘Managing Breech Flystrike’ and ‘Planning for a Non-Mulesed Merino Enterprise’ on the AWI website and the new section “Ten Steps to a Ceased-Mulesing Flock” added to FlyBoss give guidelines for breeding increased flystrike resistance and capture the experiences of woolgrowers phasing out mulesing. These will be valuable resources for woolgrowers seeking to reduce reliance on mulesing on their properties.

Appendix - Detailed response to AWI's Research, Development and Communication Strategy Framework

Areas of Investigation	Objective	Current Status/Progress Made
Breeding & Selection	Identify the incidence of flystrike resistance in the current population	<p>Project EC940 (Phase 1, 2005-10) found that 10% of sires produced progeny that could be considered resistant to flystrike without mulesing under most conditions and could be reliably used to increase genetic resistance to breech flystrike. Unmulesed progeny of the most resistant sire with no preventative treatments had a strike rate of only 2.4% under moderate to heavy challenge. In comparison, in the same environment at Mt Barker WA the average breech strike rate from birth to hogget shearing was 23% for unmulesed males and 31% for females.</p> <p>Project WP468 (Phase 2, 2010-2012) confirmed repeatability of resistance status under different climatic conditions and different levels of strike challenge and improved the accuracy with which the sheep industry can best identify resistant animals under commercial management conditions. Project ON-00169 (Phase 2, 2012-2016) demonstrated a lower breech strike incidence in unmulesed animals at Mt Barker WA of 4% to 9.5% when they were crutched as yearlings in early winter to reduce dags during the spring fly season. Flystrike incidence in the summer rainfall environment in NSW at the Chiswick site of the CSIRO breech strike selection flocks was higher than the WA site, averaging 18.1% in weaners, 7.6% in yearlings and 9.9% in adult ewes over the course of 10 years.</p>
	Determine the importance of the four main breech traits (breech wrinkle, dags, breech cover and urine stain) and their association with flystrike	<p>Phase 2 (2010-2012) provided further data confirming the consistent importance of breech wrinkle, dags and breech cover as indicators of breech flystrike under different seasonal conditions, but also suggested the importance of urine stain, scored strategically, as an indicative criterion in the Mt Barker WA flock but not the Armidale NSW flock</p> <p>Management of the WA selection flocks was modified in 2012, to include a pre-winter crutch of yearling sheep, and has provided better definition of the role of urine stain in differences between resistant and susceptible sheep. Change in crutching time led to reductions in the recorded</p>

		incidence of breech flystrike and dags in WA and has provided refinement of genetic parameter estimates. Under these conditions wrinkle was the most important indicator factor of breech strike resistance.
	Identify breech trait heritability and correlations with other important traits to be used in the creation of Australian Sheep Breeding Values (ASBVs)	Heritabilities for breech traits and correlations of these with production traits were estimated with good precision in Phase 1 and 2, aided by the collection of industry data. This is facilitating the design of more accurate breeding programs to improve breech strike resistance while maintaining or improving production. No strongly antagonistic correlations have been found that would prevent simultaneous improvement of breech strike resistance and production traits. From 2012, unmulesed animals were crutched at yearling age at the Mt Barker site to reduce dag accumulation. This has markedly decreased the observed variance and estimated heritability of breech strike incidence in the Mt Barker WA flock to levels below the Armidale NSW flock.
	Produce and extend research prototype breeding values and ASBVs for main breech traits	<p>Over the 5 years ended June 2017 (latest complete data), recording of breech wrinkle and cover and availability of ASBVs for these traits has averaged 34% and 28% respectively, of all animals recorded, with a slight downward trend over that period. Over the same period, recording of dags has remained steady at 23% of all animals recorded and may partly reflect that the trait is not easy or worthwhile recording in areas of low dag prevalence. Whilst there continues to be good coverage of different strains of Merinos with breech wrinkle and breech cover records run in different parts of the country, further emphasis of the importance of ongoing collection of data for breech traits and particularly dag and urine stain scores will be required to achieve maximum rates of gain in flystrike resistance. A Dag Consistency Score RBV (Research Breeding Value), as a prelude to creating ASBVs, should be created, to make it easier for breeders to collect information relating to dag, especially when dag prevalence is low.</p> <p>Further R&D is needed to encourage breeders of very low wrinkle sheep to collect data on more wrinkle traits (neck and body wrinkle), as there can be technical difficulties in providing ASBVs for breech wrinkle in sheep</p>

		<p>with very low variability. Use of scores for neck and body wrinkle to estimate breech wrinkle ASBV may provide a solution.</p> <p>The collection of industry records on urine stain (a further indicator of breech strike) is encouraged, but as yet no records have been submitted. Sire evaluation sites and the Merino Lifetime Productivity Project are important sources for obtaining data and if sufficient industry data becomes available, a Research Breeding Value (RBV) for urine stain will be developed. It is considered highly desirable to have ASBVs for urine stain provided in Sheep Genetics reports.</p>
	<p>Development of further breeding tools or options for identifying unknown causes of flystrike</p>	<p>Effective indicator traits have been identified and can be used to obtain worthwhile genetic gains in breech strike resistance. However, substantial variation in flystrike incidence remains unexplained for males. A number of other traits have been tested but provide little advantage over the four key indicator traits. Neck wrinkle is highly correlated with breech wrinkle and is often more accurately and easily assessed. Selecting on the basis of ASBVs for neck wrinkle can rapidly reduce breech wrinkle. Wool colour has been related to breech strike susceptibility in some instances and fleece rot is an important indicator of body strike susceptibility. ASBVs have recently been made available for these two traits through Sheep Genetics.</p> <p>The cause and roles of differences in odour between resistant and susceptible animals and differences in microbial communities in the fleece have been investigated in a series of experiments in Project ON-00169. An association has been found but results to date have been too variable for practical usefulness. A recent review (Project ON-00510) of the potential of odour and other possible risk factors underlying unexplained variation amongst sheep in flystrike susceptibility did not support further work in this area.</p>
	<p>Identify genomic associations with flystrike resistant traits</p>	<p>A large number of Single Nucleotide Polymorphisms (SNPs) for breech flystrike and breech indicator traits were identified in AWI supported projects WP550 and ON-00515, but no SNPs on their own or in small clusters were strongly enough associated with susceptibility, or with</p>

		<p>breech wrinkle, breech cover or dag score to support the creation a stand-alone genomic test. However, the results support the creation of genomic-enhanced breeding values for breech flystrike with an accuracy of 0.33 calculated, with a much larger reference population suggested to increase accuracy.</p>
<p>Grower, industry and domestic stakeholder extension, training and communications</p>	<p>Investigate and monitor changes in on-farm management strategies for breech flystrike control</p>	<p>Responses have been collated from sheep producers surveyed for parasite control practices, including the use of genetic selection strategies for breech strike resistance, in AWI/MLA project ‘WP499 Benchmarking Australian Sheep for Parasite Control’. Surveys were mailed to 6,361 producers with a 36% total reply rate. The proportion of producers using some sort of visual selection for blowfly related traits was 61% for ewes and 45% for rams while the proportion using ASBVs for blowfly related traits was relatively low (5% for ewes and 10% for rams). Indicator traits (both breeding values and phenotypic scores) used for selection were breech wrinkle (65% in rams and 51% in ewes), low dag score (31% in rams and 27% in ewes) and bare breech (28% in rams and 19% in ewes). This survey will provide a baseline for monitoring future change in flystrike control practices, including breeding for breech strike resistance. A further survey which will provide trends in these figures has been conducted and the results are currently being compiled (ON-00540).</p>
	<p>Provide woolgrowers, the domestic wool industry and relevant stakeholders updates of the RD&E outcomes and welfare advances to manage breech flystrike prevention and improve animal welfare</p>	<p>Outcomes of research have been well publicised to woolgrowers and other industry stakeholders by production of 14 ‘Breech Strike Genetics’ newsletters in WA & NSW and regularly in AWI ‘Beyond the Bale’ articles.</p> <p>Scoring systems for indirect selection traits, developed to provide practical tools for use in breech strike resistance selection programs, have been widely promoted and made freely available to sheep owners in print form and on the AWI, FlyBoss and Sheep Genetics websites. These systems form the basis for breech trait ASBVs available from the Sheep Genetics website and can also be used in traditional breeding programs.</p>

		<p>Further funding for 'ParaBoss', until 2020 has been confirmed by AWI. This project (ON-00382) manages the FlyBoss site and provides a readily accessible resource for wool growers on all aspects of flystrike control. The breeding section was updated in light of most recent research outcomes and links to material available on the AWI and Sheep Genetics websites are facilitating the rapid communication of latest research to ram breeders and woolgrowers. Use of the FlyBoss site has continued to increase with the number of visits in in the 12 months to December 2018, increasing by 37% on the corresponding period in 2017. A further innovation, a 'Ten steps to a ceased mulesing flock' for sheep producers aiming to phase out mulesing has been recently added to FlyBoss. A new 'responsive' version of FlyBoss will facilitate access from mobile phones and tablets and will assist the use of FlyBoss for on-site decision making such as during sheep selection or when deciding treatment options.</p> <p>A suite of resource material has been developed for trainers, and workshops on Breech Strike Management have been delivered by the Sheep CRC in partnership with AWI, MLA and a range of woolgrower organisations, State agencies and private consultants. The major focus up to 2018 has been on promoting breeding technologies and the use of ASBVs for breech and flystrike related traits. Notwithstanding, there is a continuing need for practical extension activities on using genetic tools to aid in breeding sheep for less susceptibility to flystrike.</p> <p>Communication of progress and advances to animal welfare organisations has continued at AWI's Animal Welfare Forum and the biennial AWI Breech Strike R & D technical update with stakeholders invited from a variety of sectors of the wool and sheep industries and the presentations uploaded on AWI's website.</p>
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