



RESEARCH REPORT:
**Prevention and
control of blowfly
strike in sheep**

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ERRATUM

A previous version of this report included an estimate of the number of sheep who die due to flystrike per year. This information has since been removed as an error was found in the calculation of the figure.

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Research Report: Prevention and control of blowfly strike in sheep

Blowfly strike (flystrike) occurs when the eggs of the sheep blowfly (*Lucilia cuprina*) hatch in moist wool and the maggots feed on the flesh of the live animal. The maggots create painful wounds which, if undetected, can debilitate the animal to the extent that it eventually dies of blood poisoning.

THE RSPCA VIEW

The RSPCA promotes an integrated approach to the prevention and control of blowfly strike in sheep. Breeding sheep that are resistant to flystrike combined with enhanced on-farm sheep management practices is the alternative to mulesing.

The RSPCA believes that it is unacceptable to continue to breed sheep that are susceptible to flystrike and therefore require an on-going need for mulesing (or other breech modification procedure) to manage flystrike risk.

The RSPCA position on mulesing is that:

- It must only be done as an interim measure where a flystrike-resistant sheep breeding and selection program is in place
- It must not be done if other humane procedures can protect sheep from flystrike
- It must only be done in a location where it is known it will reduce the incidence of flystrike
- It must only be done by a competent and accredited person
- It must only be done on a well-restrained lamb that is less than 8 weeks of age
- It must only be done using appropriate pain relief; that is, a combination of topical anaesthetic and non-steroidal anti-inflammatory drug
- It must not be done on older animals unless under anaesthesia and with appropriate aftercare to help healing
- It must not be done on lambs sold at an early age for meat.

The RSPCA urges the wool industry to continue to invest research, development and extension effort into a comprehensive flystrike-resistant sheep-breeding program. On-farm extension to facilitate the rapid adoption of breeding solutions must be a priority for the wool industry.

The RSPCA urges retailers sourcing Australian wool to indicate to suppliers their intention to purchase only non-mulesed wool within the shortest possible time frame, noting that such wool should be sourced from flystrike-resistant sheep.

The wool industry's research, development and extension program must be underpinned by achievable milestones and provide regular updates to the general public as a means of demonstrating the wool industry's genuine commitment to phasing out mulesing in the shortest possible term.

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INTRODUCTION

Increased scrutiny of painful farm animal husbandry practices such as mulesing, has led to public and retailer demand for 'non-mulesed' wool. For over a decade, the wool industry's research and development (R&D) and marketing body has invested in an extensive program that aims to provide wool growers with alternative methods of preventing and controlling flystrike in the breech area including breeding and pain relief options. Despite these on-going efforts, the vast majority of woolgrowers continue to mules their sheep because a large proportion of Australian Merino sheep are still highly susceptible to flystrike.

The RSPCA advocates for the selection and breeding of sheep that are resistant to flystrike and do not require mulesing or other breech modification procedure to achieve this.

The RSPCA supports an integrated approach to the prevention and control of blowfly strike and this research report examines measures to prevent flystrike in the absence of mulesing. This research report is not limited to Merino sheep for wool production - non-Merino and first cross prime lamb mothers are also routinely mulesed.

FLYSTRIKE

The most prevalent cause of flystrike in Australia is the sheep blowfly, *Lucilia cuprina*. It initiates more than 90% of all strikes on susceptible sheep (NSW DPI 2007). Female blowflies lay eggs in the fleece of the sheep, and the resulting maggots cause mechanical damage by feeding on the flesh of the sheep, and chemical damage due to the ammonia they excrete. The sheep blowfly thrives in warm and humid environments. The female blowfly is particularly attracted to sheep with wool stained and wet from urine and feces. However, it is not the wet wool but the subsequent skin irritation it causes that attracts the fly and creates the ideal environment for her to lay her eggs (QDPI&F 2005b). Sheep that are affected by fleece rot or dermatophilosis (lumpy wool or dermo) are also susceptible to blowfly strike (Norris et al 2008).

Blowfly strike (or flystrike as it is commonly known) causes considerable pain and suffering. Flystruck sheep have increased rectal temperature, show rapid breathing, and suffer weight loss caused by loss of appetite (Broadmeadow et al 1984). Affected animals may eventually succumb to blood poisoning and die if left untreated. Flystrike is a seasonal issue, and individual sheep can experience recurring bouts of flystrike every year. Prime (meat) lambs, because of their plainer bodies and the fact that they are slaughtered at an early age, have a significantly reduced risk of becoming flystruck.

Flystrike is widespread among the Australian sheep flock. This is due to a combination of factors, including the Merino sheep breed's general susceptibility to flystrike, the presence of *Lucilia cuprina*, the extensive nature of Australian sheep production (and the subsequent reduction in frequency of monitoring), and Australia's climate (Phillips 2009). The introduction of the Vermont Merino – an animal with extremely wrinkly skin - in the late 1800s, resulted in significant outbreaks of flystrike (Karlsson et al 2012) and as far back as the 1930s (Seddon 1931a) it has been known that heavily-wrinkled sheep, particularly those with a soiled breech area, are most susceptible and over 90% of strikes generally occur in the tail and breech area (AWI 2007). However, flystrike may also occur on the body of the sheep (a major problem in warm, humid conditions), the poll, the pizzle and on wounds. The type of strike (body vs. breech) can vary greatly depending on the ensuing conditions. In addition, individual sheep vary in their ability to resist external parasites due to variation in the immune response.

Flystrike is thought to cost the wool industry \$173 million (Lane et al 2015) a year in flystrike treatment/prevention costs and loss of production, including sheep deaths, sheep weight loss, and loss of wool growth/value. Mortalities have been estimated to occur in around 10% of flystruck adult sheep and 20% of flystruck yearling sheep (Lane et al 2015).

MULESING

In 1929, John Mules developed a surgical technique for reducing the amount of wrinkle in the breech area of sheep in order to lower the risk of flystrike (Beveridge 1984). This operation became known as ‘mulesing’ and, because it is highly effective in preventing flystrike, continues to this day.

The purpose of the mules operation is to reduce the susceptibility of sheep to flystrike by making the breech area less attractive to flies. With less wrinkle and more bare skin, feces and urine cannot accumulate thereby significantly reducing the risk of flystrike. The mules operation also results in a number of secondary benefits, for example, reduced wool stain and dags, ease of shearing and crutching, lower chemical residues in the wool, and a reduction in labour costs associated with inspection and treatment of animals (James 2006).

Mulesing involves the removal of crescent-shaped pieces of skin, from the base of the tail down either side of the perineal area, using sharp shears designed specifically for this procedure. In addition, a strip of skin is removed from each side of the tail. The resulting wound, when healed, increases the bare area while at the same time reducing the amount of wrinkle.

Mulesing is usually carried out during lamb ‘marking’ when the animal is between 6 to 10 weeks of age. Lamb marking may not only include mulesing but a series of other painful procedures that are all carried out at the same time: tail docking, castration (for males), ear notching or ear tagging, and vaccinating (Windsor 2013). In 2016-17, an estimated 13.5 million Merino lambs were marked (ABS 2018) with the majority of these lambs being mulesed (see ‘Pain relief’ section below).

Mulesing is performed without anaesthesia, and pain relief is not always used (see ‘Pain relief’ section below). The operation is quick; however, the acute pain is long lasting – at least up to 48 hours (Lee et al 2007) or from several days to several weeks (Small et al 2018b). The resulting wound bed takes 5-7 weeks to completely heal (Lepherd et al 2011b). Mulesed lambs will socialise less (Fell et al 1989), lose weight in the first two weeks post mulesing (Chapman et al 1994), exhibit behavioural indicators of pain including prolonged hunched standing and less time lying and feeding (Fell et al 1989), and stand in a hunched position (Paull et al 2007; Hemsworth et al 2012). The effect on gait and growth may be apparent for up to three weeks following the procedure (Hemsworth et al 2009). Following mulesing, lambs may avoid humans and, in particular, the person who carried out the procedure, for a period of 3 to 5 weeks (Edwards 2012). This avoidance behaviour is indicative of fear and the extent to which the animal experiences the procedure as aversive. By mulesing lambs between 2 to 8 weeks of age, the size of the wound and the resulting impact on the lamb is reduced.

In addition to this behavioural response to mulesing, a significant stress response shown by high blood cortisol levels and elevated neutrophil:lymphocyte ratio (this ratio increases as a result of a stressful event) up to 48 hours post mulesing is also evident (Edwards 2012). Similarly, haptoglobin (also found in blood and used as an indicator of the degree of tissue damage and inflammation) is significantly elevated for up to a week post mulesing (Edwards 2012). And, finally, lambs lose weight in the week following mulesing and have reduced weight gain compared to non-mulesed lambs for several weeks following the procedure (Edwards 2012).

Both mulesing and flystrike cause substantial challenges to sheep welfare. Mulesing is a quick and effective method of controlling flystrike in Merino sheep, hence its popularity with producers. However, mulesing results in poor welfare both during and after the procedure and the following section of this report discusses alternatives to mulesing that aim to improve sheep welfare.

AN INTEGRATED APPROACH TO FLYSTRIKE PREVENTION AND CONTROL

The key to effectively managing flystrike in the absence of mulesing is to make the sheep less attractive to the blowflies through an integrated approach to blowfly control (AWI 2018b; QDPI&F 2005a). Such an approach includes:

- monitoring blowfly activity;
- strategic application of chemical treatments (should they be required to control flies);
- animal husbandry and farm management practices that take into account the timing of shearing and crutching;
- effective tail docking (should that be required);
- effective control of scouring (especially the control of dags and worms);
- improved body condition and general health to increase robustness;
- shorter joining (3-6 weeks) and early weaning (10-12 weeks) for more flexible management; and
- regular inspection of the flock.

These options for preventing and controlling flystrike in the absence of mulesing should be accompanied by a breeding and selection program that aims to reduce wrinkle, dag and urine stain and increase the bare area in the perineal region, combined with removing susceptible sheep from the flock.

Together these proactive strategies will have a cumulative effect on the flock's overall resistance to flystrike. A dedicated decision support tool called [FlyBoss](#) is available to producers to assist in the decision-making processes that lead to effective flystrike control.

It is unacceptable to continue to breed sheep that are susceptible to flystrike and therefore require an on-going need for mulesing (or other breech modification procedure) to manage this risk.

Breeding and selection

As early as 1931, researchers concluded that breeding could reduce flystrike incidence (Seddon et al 1931b) but with the emergence of mulesing and, later, mulesing in combination with shearing, crutching and chemical treatments, breeding received little attention. Many of the fine-wool Merinos in particular, still have the wrinkle phenotype (Windsor et al 2013).

The breeding of flystrike-resistant sheep is a long-term process whereby animals with a naturally bare or low-wrinkle breech area are selected from or introduced into the flock in order to produce progeny with no or low wrinkle in the breech area and a large, bare perineal area.

In addition to bare breech traits, selection pressure focuses on reducing the flock's overall disposition to flystrike by removing animals that have fleece rot (a heritable infection), are repeatedly flystruck have low immunity, or are repeatedly affected by worms and scours (AWI 2007). Selection pressure will also depend on the environment in which sheep are raised. If dags and scours are a regular occurrence, then selection against dags will reduce the risk of breech strike (Tyrell et al 2014). Accumulation of dags is a significant contributor to breech strike regardless of whether sheep are in summer or winter rainfall regions (Karlsson et al 2012). Keeping a record of sheep that have been affected by flystrike will identify those that are repeatedly struck – one quarter of strikes are found on previously affected animals (AWI 2008a).

Key indicator traits for breech strike are dags, urine stain, wrinkle, wool coverage in the breech area, and wool colour (Edwards et al 2009; Karlsson et al 2012; Scholtz et al 2010). Breech strike itself is moderately heritable (Dominik et al 2017) but these key indicator traits can be used to indirectly identify flystrike-resistant animals,

including through use of visual score guides (available for dags, breech wrinkle, body wrinkle, urine stain and fleece rot) and Australian Sheep Breeding Values (available through [MerinoSelect](#) since 2009). Selection for a barer breech area may reduce fleece weight, skirtings and belly weight slightly (AWI 2008a) although others have found that selection for a barer breech has little if any detrimental impact on key wool production and wool quality traits (Hatcher et al 2017). Since 2017, the sire lists in the [MerinoSelect](#) database include key breech traits (wrinkle, breech cover and dag) allowing wool growers to understand the association between one or more of these traits and how these affect production and wool quality traits. For example, where sheep with lower wrinkle have lower fleece weights, woolgrowers can improve fleece weight by using the Australian Sheep Breeding Values to select rams with the best fleece weights for low wrinkle. It would benefit the industry greatly if more animals with desirable (low) scores in the key breech traits were included in the database.

In a Mediterranean environment (i.e. winter rainfall), flystrike tends to occur between mid-October and end-December, and the presence of dags in sheep is strongly correlated with early breech strike in these environments. Breeding for low dag score could be used to breed for breech strike resistance, with urine stain, neck wrinkle, breech and face cover being additional indicator traits in a Mediterranean environment (Greeff et al 2013). In another environment (New England, NSW), selecting for breech cover or wrinkle at 10-13 months of age, would, over time, reduce either wool cover or wrinkle on the breech thereby reducing the incidence of flystrike (Hatcher et al 2015). Research trials have shown that, in a certain climatic environment and using certain bloodlines, the bare-breech trait is moderately to highly heritable and does not significantly affect other wool traits such as fibre diameter, staple length and strength, and greasy fleece weight. For example, a study in 2017 (Hatcher et al 2017) found that selection for low breech cover, low breech, body and neck wrinkle, had little if any detrimental impact on key wool production and wool quality traits in Merinos in the New England environment. In general, there is greater variation in wrinkle and lower wrinkle score in sheep with medium fibre diameters than in sheep with finer fiber diameter which tend to have higher wrinkle. Where there is greater variation in wrinkle, there is greater potential for genetic progress towards lower wrinkle (pers.comm. Geoff Lindon 2018).

In the future, gathering of phenotype data relating to breech strike, breech cover, wrinkle score and dag score could allow for the development of genomic breeding values (GEBV) or identification of genetic markers and, with these, provide an avenue for genomic testing to identify animals that are resistant to breech strike (Dominik 2018).

Breeding and selection - SRS Merino

Most Merino sheep in Australia are wrinkled. However, a plain-bodied Merino sheep exists and is called the SRS Merino (SRS stands for soft rolling skin). This Merino type has been bred in Australia since the late 1980s and now comprises about 10% of the Australian Merino sheep flock. Rather than relying on wrinkle (i.e. large skin surface area) to obtain high fleece weights, the SRS Merino has a loose and supple skin that is closely associated with high fibre density and length (i.e. more wool per area of skin) and wool of high quality (Watts et al 2017). The high fibre density is achieved through the presence of secondary fibre follicles in the skin. The loose, supple, non-wrinkly skin of the SRS Merino dries rapidly, ensuring these sheep are resistant to fleece rot and flystrike, and do not require mulesing.

Introducing plain-bodied sires into a wrinkly flock that requires mulesing is said to dramatically change the requirement for mulesing within 5 years. In the SRS Merino, the traits associated with wool production (fleece weight and fibre diameter) and wool quality (softness, lustre, bundle size, skin) are moderately to highly heritable and correlated with high fleece weight and low fibre diameter (Brown et al 2002 in Greeff 2009; Watts et al 2017). The visual classing system based on fibre density and length also sees an increase in numbers of secondary follicles (Watts et al 2017). Follicle density, in turn, is highly negatively correlated with fibre diameter (Moore et al 1989; Moore et al 1998). Initially selecting traits qualitatively, based on skin type (e.g. SRS Merino), rather than quantitatively, using an index-based selection method (e.g. fibre diameter or

fleece weight), is unconventional but has proven merit (e.g. Daily et al 1997; Kopke et al 1998; Charry et al 1999) although others have suggested this is not the case (e.g. Mills et al 1998).

Some SRS Merinos have naturally short tails and this presents an opportunity to select for short tails, thereby also removing the need for tail docking these sheep.

Breeding - getting started

Breeding for flystrike resistance is the permanent solution to mulesing and some woolgrowers are already well on this track. The sooner woolgrowers introduce a breeding program, the sooner improvements will be seen and the sooner the costs and animal welfare impacts of managing and treating flystrike will be reduced. The wool industry's dedicated decision support tool - [FlyBoss](#) – suggests four key steps to get the processing going:

1. Use Australian Sheep Breeding Values to select rams with low wrinkle, low dag and low breech cover
2. Assess ewes for fleece rot, wrinkle, dag and breech cover
3. Develop a joining strategy that reduces the proportion of at-risk ewes that are susceptible to fleece rot and have high wrinkle, dag and breech cover
4. Assess lambs based on their flystrike risk and aim to reduce proportion of lambs needing to be mulesed, e.g. by removing them from the flock.

The greater the selection pressure – i.e. selecting for flystrike resistance traits in both ram and ewe – the more quickly the desired results will be achieved.

Monitoring blowfly activity and reducing blowfly populations

Blowfly activity is monitored at those times of the year when conditions are likely to be warm and humid as this is when the blowfly is most active. Blowfly numbers increase as temperatures go up (Phillips 2009).

Blowfly populations can be monitored and reduced in some situations using fly traps at these strategic times in the year. A trap specifically developed to lure the sheep blowfly is readily available and has been shown to reduce the incidence of flystrike by 46% (Ward 2001). Flies entering the trap die from lack of water and food, as they cannot escape. The lure lasts for up to 3 months and the trap is most successful in areas where sheep tend to congregate, for example, near water (Tellam et al 1997). Guidelines for using a lure will be specific to the region in which it is being used. The lure is most effective when exposed to the sun, sheltered from the wind, and attached to posts rather than trees. Effectiveness is enhanced when adjacent farmers all use traps at the same time.

Paddocks that are wet, heavily shaded and sheltered provide ideal conditions for blowflies. Weaners, heavily wrinkled sheep and previously struck sheep are at high risk of becoming flystruck if moved to such high-risk paddocks (AWI 2007).

When used as part of an integrated approach to controlling flystrike – for example when used in combination with strategic shearing and crutching – flytraps have the potential to reduce or eliminate the need for chemical fly treatments.

Preventative chemical fly treatments

Chemical treatments are part of an integrated approach to control flystrike – they are not a stand-alone option. Blowflies are exposed to the chemical treatment as they land on the wool and, depending on the active ingredient, the chemical works by interfering with the larval stage of the blowfly's lifecycle, by affecting the blowfly's nervous system, or by reducing motor activity and causing paralysis of the blowfly (DAFWA n.d.).

Chemical treatments are most commonly applied when flystrike is expected, or to provide protection during the period of the year when the risk of flystrike is high (Horton 2015). If chemical fly treatment is necessary, it has been found to be more effective if applied to the breech six weeks after shearing or crutching rather than immediately after shearing or crutching (James et al 2009). It is recommended to avoid the use of chemicals within three months of shearing unless treatment and/or prevention is necessary, in which case compliance with wool and meat withholding periods is required. To reduce the number of flystrike incidents as well as the cost of chemical treatments, the timing of shearing and crutching and the application of the treatment should be carefully managed (Lucas et al 2013). Any chemical applied prior to shearing is removed along with the wool (Horton 2015).

An additional beneficial effect of chemical fly treatments is that, by reducing the capacity of flies to lay eggs, fewer maggots develop into pupae. This reduces the pupae population in the soil, with fewer flies emerging the following spring. It has also been suggested that applying chemical treatment before flies emerge in early spring in regions with moderate to high flystrike risk, will kill emerging flies before they are able to produce offspring (Horton 2015).

The breeding of less wrinkly sheep and the need to avoid residues in wool and lanolin should see the more strategic use of chemical treatments, i.e. with consideration of the timing of shearing and crutching, and specifically selected to target the blowfly. An additional consideration when using chemical treatments, particularly where there is heavy reliance on chemical treatments, is the development of resistance in the fly larvae. With only a small number of chemicals available (cyromazine, dicyclanil and ivermectin) this further highlights the importance of limited and strategic use of chemicals to protect sheep against flystrike.

Crutching and shearing

Crutching is the removal of wool from between the back legs and around the tail of sheep. It may also include removing wool from the head (particularly rams) and from the bellies of male sheep. Shearing, on the other hand, is the complete removal of wool. The timing of crutching and shearing is key in reducing the risk of flystrike. Because the sheep blowfly thrives in warm, moist conditions, the periods of greatest risk of flystrike occur when rainfall is followed by warm weather or vice versa.

With shearing or crutching, maximum impact is obtained if it is done just prior to or at the start of the period of expected maximum blowfly activity. Although, it should be acknowledged, that timing of shearing is also affected by availability of shearers. Flystrike risk is reduced following shearing and reaches maximum risk around 4 months after shearing (Horton 2015).

Twice-yearly crutching is another strategy woolgrowers use to reduce the flystrike risk. For example, an autumn and spring crutch for those shearing in summer, and a late-spring and autumn crutch for those shearing prior to lambing in spring (8x5 Wool Profit Program 2008). Alternatively, a smaller 'bung-hole' crutch could be as effective as a second crutch (AWI 2008d).

Tail docking

Wool-bearing skin on and near the tail can be subject to flystrike, particularly as the wool grows longer and becomes stained with urine and feces (James 2006). The length of the tail also affects susceptibility to flystrike. Studies carried out in the 1930s and 1940s, demonstrated that long to medium-long tails, i.e. just below the lower border of the natural bare area and just below the tip of the vulva respectively, gave the best protection against flystrike in unmulesed Merinos (Lloyd 2012). In these studies, shorter tails also took longer to heal and were more likely to become infected.

Muscle controlling movement of the sheep's tail and skin underneath the base of tail are designed to push feces out and over the wool in the breech area thus avoiding contact with the wool. If a tail is docked too short, this will result in the loss of that skin, the loss of muscle and the loss of the ability to direct feces

outwards thereby increasing the risk of a soiled breech area (dags) which is attractive to flies. Sheep with short or butted tails are more susceptible to breech strike for this reason (Watts et al 1979; Lloyd 2012). Short tails (as well as shearing and mulesing) increase the risk of bacterial arthritis in lambs, which is caused by bacterial infection at the site of the wound (Lloyd et al 2016).

By avoiding short tails (the tail of ewe lambs no shorter than the lower tip of the vulva (Watts et al 1979) and the tail of wethers no shorter than the lowest point of the anus), these areas will also be protected from sunburn and cancer (James 2006). Effectively, this means docking no shorter than at the third palpable joint. Tail docking is painful and where it is considered necessary it must be done by a competent operator using pain relief and the lamb then provided with appropriate care to minimise infection and promote healing.

Control of dags and worms

Dags are formed when feces soil the wool in the breech area. Reducing dags is therefore important to reducing the attractiveness of this area to flies.

Dags can be caused by scouring (diarrhoea) which, in turn, could be due to worm burdens. Effective treatment of worms using a targeted drench should quickly stop the scouring. Scouring could also be related to worm-immune sheep becoming hypersensitive to worm larvae ingested after a long period of worm absence. In some sheep, an abnormal immune response to these larvae results in inflammation of the gut, which causes the scouring.

Breeding and selecting sheep that are resistant to worms may be the long-term solution to reducing worm-related scours while at the same time managing the problem of drench resistance (Bisset et al 2001; Gray 1997). Selecting for less dags (or low dag weight) is part of this approach (Larsen et al 1999; Greef et al 1997; McEwan et al 1997; Scobie et al 2010) although there has been limited progress to date with regard to breeding for less dags (pers.comm. Geoff Lindon 2018). A dedicated decision support tool called [WormBoss](#) is available to producers to assist in controlling worms in sheep.

Scouring is not necessarily related to worm/larvae burden and may have other causes (AWI 2008b; Watts et al 1978). Diet, for example, can also lead to scours. Improved pastures in higher rainfall areas; rain-soaked grass-dominant pastures, including rye grass pastures, which have rapidly regrown following a dry summer; cereal crops or cereal grain; and sudden changes of diet can all lead to scouring (Watts et al 1979).

A strategy of placing high-risk animals in the lower-risk paddocks (i.e. dry, lightly shaded and sheltered from rain) may assist in reducing scours and subsequent dags.

Strategic timing of shearing and crutching also helps to reduce dags.

General flock management

Key learnings from interviews with 40 wool-growing enterprises that have phased out mulesing (AWI 2018b) found that improving sheep body condition through increased nutrition and improving general sheep health by reducing parasite load and disease were all factors that reduced flystrike risk. Many of these enterprises also introduced joining periods of 3 to 6 weeks to reduce any impact of flystrike during lambing when opportunities to intervene are limited due to the risk of mismothering. Early weaning (10-12 weeks) was another strategy used by these enterprises, which, in combination with early joining, allowed 6-monthly shearing to fit into the calendar year by shearing ewes and weaning lambs at the same time. These less traditional flock management strategies proved to be effective at managing flystrike risk.

ALTERNATIVES TO MULESING

The wool industry has sought to develop viable and humane alternatives to mulesing. To date, none of these alternative solutions has had wide industry uptake and/or been proven to be commercially viable.

The RSPCA believes that humane, alternative practices that preclude the need for mulesing or breech modification should be adopted. Any breech modification procedure should only be considered an interim, short-term solution that accompanies a breeding program that focusses on flystrike resistance, and is carried out only where absolutely necessary to manage at-risk sheep. Fisher (2011) argues that for a high-end product such as fine Merino wool, the welfare advantages and benefits of market access of sheep that do not have to be mulesed or modified are incontestable.

It is unacceptable to continue to breed sheep that are susceptible to flystrike and therefore require the need for breech modification (including the mulesing alternatives outlined below) to manage flystrike risk.

Clips

The development of clips aimed to mimic the effect of the mules operation and in 2007 commercial prototypes were available for testing (Lloyd et al 2010). Application of clips is a non-surgical procedure whereby folds of skin on either side of the perineal area as well as the tail are clamped together with moulded plastic clips. Four clips are required – one on each side of the tail and one on each side of the breech area next to the tail. The clips need to be left on for at least 4-6 days to have the desired effect (Evans et al 2012b). The loss of blood supply causes occluded skin flaps to die and fall off after about 2 weeks, extending the bare area. Compared to the mulesing procedure, the effect of clips in terms of reducing breech wrinkle, breech cover, dags and urine stain is less but the effect on the tail bare area is good, providing up to 80% control of flystrike (AWI 2011). Clipped sheep have less dag and urine stain compared to unmulesed sheep so less time is spent on crutching clipped sheep (Larsen et al 2012). However, overall, clipped sheep require similar flystrike prevention strategies to unmulesed animals (Larsen et al 2012).

The results of research trials (Hemsworth et al 2009) indicate that clips offer a significant welfare advantage over mulesing in terms of lamb survival, daily weight gain and pain response. In terms of flystrike, clipped lambs are more susceptible than mulesed lambs but better protected than untreated lambs (AWI 2008c). Clipped lambs have a greater breech bare area and lower wrinkle, dag and urine scores compared to untreated lambs (Playford et al 2012) although not to the extent achieved through mulesing (Evans et al 2012a). The clips have better results in terms of greater bare area when applied to loose-skinned lambs compared to tight-skinned lambs; similarly, less-wrinkled lambs have a better bare area result than highly wrinkled lambs following clip application, as do lambs with less dag (Rabiee et al 2012).

Compared to mulesing without pain relief, clip application is less painful with lambs spending less time standing immobile with their head down and more time walking and feeding than mulesed lambs (Hemsworth et al 2012).

Clips must be applied by trained operators to ensure correct use. However, adoption of clips was low due partly to poor results on sheep with heavy wrinkle and heavy dags (clips appear to be more effective on sheep with lower breech wrinkle, lower breech cover and less dags). Biodegradability of the plastic clip was also a concern as producers were reluctant to find plastic clips strewn among their paddocks, and double handling of the sheep is required to remove the clips before they drop off in the pasture. Clips are no longer available on the market.

Needleless intradermal injections

This procedure uses a needleless applicator to inject directly into the skin a special formulation which causes skin cells to die and a thick scab to form at the injection site. The skin tissue surrounding this scab closes in under the scab and, when the scab falls off, it leaves an area of stretched skin similar to the result of mulesing (Lee et al 2010). The procedure is non-surgical.

Various chemical formulations have been trialled. For example, when the effectiveness of one particular formulation (cetrimide) was trialled, signs of significant discomfort and pain were noted in treated lambs and, consequently, further research with cetrimide ceased (Levot et al 2009; Colditz et al 2009a; Lopherd et al 2011a). Use of an anti-inflammatory drug (carprofen) following the cetrimide intradermal did reduce the time lambs spent in abnormal (pain-related) behaviours such as hunching and stiff walking (Colditz et al 2009b), confirming that this intradermal treatment was painful.

Another intradermal formulation – sodium lauryl sulphate – was compared to clip application and mulesing without pain relief (Hemsworth et al 2009). Both alternatives were found to be more humane than mulesing without pain relief and both alternatives showed no significant behavioural differences compared to the untreated control group. However, both the clips and particularly the intradermal treatment showed elevated cortisol (stress) and haptoglobin (response to inflammation and tissue trauma) concentrations compared to the control; and, the neutrophil to lymphocyte ratio (changes in immune function) was higher in the intradermal treatment. These results from the blood analysis indicate “moderate” stress and the effect of the tissue trauma resulting from the alternative treatments. It seems both alternative procedures are painful, although less intense and not as long lasting as mulesing without pain relief.

Another study (Edwards et al 2011) comparing the clips and sodium lauryl sulphate intradermal treatment with mulesing without pain relief found that the impact of the non-surgical treatments was less than mulesing. Lambs in the clip and intradermal treatments differed little behaviourally from control lambs other than spending more time kneeling in the first 2 hours following treatment. They also had higher plasma cortisol concentrations than control lambs. Both clip and intradermal treatments caused far less acute behavioural change than surgical mulesing.

Whereas the studies above compared sodium lauryl sulphate intradermal treatment to mulesing without pain relief, another study looked at a comparison with mulesing using topical pain relief (Colditz et al 2010). In this study, lambs treated with the intradermal spent less time in abnormal behaviours (hunched standing, stiff walking, pawing, lying down) than lambs mulesed with pain relief. Blood analysis showed the intradermal taking effect within 12 hours (fever) accompanied by an inflammatory response similar to mulesing but not as long lasting (7 days versus 14 days).

The use of an insecticide to control flies after the procedure is important as the needleless injection causes a high-protein exudate to come out of the holes made in the skin - the exudate is attractive to flies.

By 2011, research was continuing to progress on the applicator, particularly the precise areas to inject, and on ensuring that the right dose enters the skin and does so without being contaminated or obstructed by the lamb's fleece or the thickness of the skin. Further trials also aimed to improve the speed of the treatment as well as improve the results for wool cover on the tail to more closely resemble the results after mulesing (AWI 2011).

The Australian Pesticides and Veterinary Medicines Authority (APVMA) registered the sodium laurel sulphate intradermal technology (SkinTraction®) in May 2015. However, registration included strict use requirements, e.g. the need for sheep to be >30kg and >12 months old. A key concern was the risk of the active ingredient – sodium laurel sulphate – moving through the skin and into underlying tissue, including muscle. These restrictions on the use of SkinTraction® severely limited its use and made it effectively unviable for most producers.

Vaccines

The research into a vaccine against flystrike has not yet led to a commercial success (Elkington et al 2007). It appears that this is mainly due to sheep having a poor level of natural immunity to blowfly strike. Further research is required to develop a vaccine that promotes immunity and targets the antigens that are involved in wound initiation and parasite growth. In the last decade, advancing technology (including genomics) have allowed the identification of genes in the blowfly that are important for larval development and which, in the future, may be able to be knocked down or disrupted with a targeted vaccine (Perry 2018).

Topical applications

Certain compounds can be applied directly to the skin of the animal causing the treated region to slough off and leave an area of stretched, bare skin similar to mulesing (Phillips 2009). Compounds such as phenol and caustic potash were applied in the past but are no longer used due to OH&S concerns and length of time required to apply the product. Application of liquid nitrogen was also trialed whereby excess skin on the lamb's breech and tail is tightly clamped and liquid nitrogen applied to the clamped skin until it is fully frozen. The clamp is then removed and treated skin eventually falls off. The method is painful and no benefits in terms of reduced pain were found over mulesing regardless of whether pain relief was provided (Small et al 2018a). An adaptation of this liquid nitrogen technology is under development and aims to reduce the amount of liquid nitrogen required while at the same time achieving a tertiary freeze with no pain response. Adaptations of the method aside, while ever liquid nitrogen is applied directly to the skin, the process will still be painful to the lamb.

Sheep odour

In an effort to determine whether the odour of sheep has a role to play in their attractiveness to the blowfly *Lucilia cuprina*, sniffer dogs were trained to identify wool from sheep resistant to flystrike. When tested on a selection of wool samples, dogs were able to sniff out the wool from resistant animals with 82% accuracy. It is suggested that differences in odour between sheep could be used as a future indicator trait to select for flystrike resistance (Sandeman et al 2014).

The fly genome

Insecticides have been used for many decades to treat flystrike; however, their excessive use has led to issues with chemical residues in the fleece and resistance in the blowfly *Lucilia cuprina* with warnings that it is only a matter of time before the blowfly develops resistance to all available classes of insecticide. So, in addition to breeding flystrike resistant sheep, the possibility of transforming the blowfly is being investigated. The recent sequencing of the *Lucilia cuprina* genome offers future prospects for finding ways to prevent flystrike (Anstead et al 2017). Blowfly control strategies could be developed that use knowledge of the genes responsible for blowfly larvae feeding off sheep or, in future, it could be possible to employ gene editing technology to provide more effective control options (Sandeman et al 2014), e.g. knocking out the gene responsible for the blowfly's ability to see or smell (Trent 2018).

Laser epilation

Two varieties of human epilation (hair removal) lasers were trialed on superfine Merinos. The sheep were first clipped around the flank, the breech, pizzle as well as the eyes, and then any remaining wool was removed by the laser treatment. The sheep appeared to tolerate the treatment well. When, after 6 weeks, the scab resulting from the laser treatment fell off there was some scarring and evidence of wool growth in unscarred skin. Wool growth was not permanently prevented by the laser treatment (Colditz et al 2015). At this stage, it is not known whether further work in this area will be pursued.

PAIN RELIEF

A 2018 survey of 1200 Merino woolgrowers across Australia showed that 96% of all growers surveyed who mules their lambs do so at lamb marking (AWI 2018a; Sloane 2018). The same survey showed that 70% of producers mules their ewe lambs and 63% of producers mules their wether lambs, with at least 85% of lambs receiving pain relief at mulesing (Sloane 2018). This is significantly more than the usage of pain relief declared through the mulesing status declarations on NWDs even taking into account that as at 31 October 2017 only 65% of bales were accompanied by an NWD (see 'National Wool Declaration' section below). It is also significantly more than a 2014 Sheep CRC survey which found that 61% of Merino lambs were mulesed with pain relief (Sheep CRC 2014) and a 2016-17 unpublished joint survey conducted by Australian Wool Innovation and Meat & Livestock Australia which found that around 77% of Merino lambs were mulesed with pain relief (pers.comm. Geoff Lindon 2018).

The RSPCA's position is that where an invasive procedure such as mulesing or other painful breech modification is carried out, it must be accompanied by adequate, timely and effective pain-relieving and/or pain-preventing products.

The development of long-acting drugs administered before or at the time of the mulesing operation has been on-going for over a decade (Paull et al 2007; Paull et al 2008). The purpose of this research is to develop drugs that can reduce or eliminate the pain of the mulesing or other breech modification procedure.

In 2006, Tri-Solfen[®] (Bayer HealthCare 2006), a topical anaesthetic for application post mulesing, became available under permit to producers. Tri-Solfen[®] is a spray-on local anaesthetic formulation containing lignocaine (a fast-acting pain relief), bupivacaine (a longer acting pain relief), adrenaline (to reduce blood loss) and cetrimide (an antiseptic) (Windsor et al 2013). Tri-Solfen[®] provides pain relief for up to eight hours following mulesing (Lomax et al 2008; Windsor et al 2016). There has been a steady uptake of the topical anaesthetic since its introduction with over 60% of mulesed lambs having topical anaesthetic applied following mulesing by early 2011 (Bayer 2011) and up to 85% by 2018 (Sloane 2018). Tri-Solfen[®] was registered by the APVMA in 2012 and, in 2014, rescheduled as a Schedule 5 rather than a Schedule 4 drug allowing it to be sold 'over the counter' rather than having to be prescribed by a veterinarian. Since its rescheduling, around 75% of all Merinos mulesed have received Tri-Solfen[®] (AWI 2018a).

Tri-Solfen[®] is sprayed onto the mulesing wound. The gel-like nature of the product ensures it adheres to the wound and provides a barrier to help keep the wound clean and promote healing. Pain relief provided by Tri-Solfen[®] may last 12-24 hours largely due to the protective barrier of the gel (Lomax et al 2013) following the procedure but, of course, Tri-Solfen[®] does not diminish the acute pain of removing skin from the breech area and the tail. Providing pain relief to lambs at marking will help lambs 'mother up' after the procedure and have their first drink more quickly compared to lambs that have had no pain relief (Lomax et al 2013). A delay in mothering up risks lambs being susceptible to exposure and possible death.

In 2016, an oral analgesic product (Ilium Buccalgescic OTM) became available to producers. It is a Schedule 4 drug that must be obtained through a veterinarian. The buccalgescic is applied against the inside of the sheep's cheek via a dosing gun immediately prior to the mulesing procedure. The active ingredient in this oral pain relief is meloxicam, a non-steroidal anti-inflammatory drug that is quickly absorbed in the blood stream within 15-20 minutes of administration, reaching maximum concentration after 2.6 hours (Small et al 2018b). A field trial using topical pain relief (Tri-Solfen[®]) and the oral pain relief separately and in combination, found that the topical pain relief acted the fastest and reduced pain-related behaviours such as hunched standing for 4 hours post mulesing; the oral pain relief did not become effective until 2 hours after mulesing but lasted at least 6 hours; combining the two products reduced pain-related behaviours for 6 hours (the total observation period). Two days later, the combination of products resulted in less behavioural impacts being observed compared to the topical pain relief on its own (Small et al 2018b)

Metacam®20mg/ml, an injectable form of meloxicam, also became available in 2016 and is designed to alleviate pain and inflammation, e.g. post mulesing. The product is injected subcutaneously high on the neck behind the lamb's ear prior to the procedure.

Best practice pain relief would require the use of a topical anaesthetic in combination with a non-steroidal anti-inflammatory drug.

TREATMENT OF SHEEP WITH FLYSTRIKE

Preventative strategies will significantly reduce the risk of flystrike within the flock. However, they may not eliminate the incidence of flystrike altogether.

To reduce animal suffering, flystruck sheep need to be identified quickly – for example, through regular monitoring of the flock – and treated immediately. An animal that has been struck can be identified by the presence of dark areas on the wool, be isolated from the flock, lose appetite (resulting in marked loss of body condition) and/or be rubbing or biting the affected area.

If an individual animal is struck, treatment consists of shearing the affected area as well as at least 5 cm of unstruck wool around it close to the skin. Maggot trails through the wool are followed to ensure that other areas have not been affected. Shearing will remove many of the maggots and will help the area to dry out (NSW Agriculture 1999). Removing any remaining maggots and placing the affected clippings into an airtight bag will kill the maggots. A registered dressing (NSW DPI 2004) is then applied and the sheep returned to the flock and monitored to determine that it is recovering well. The dressing kills any remaining maggots and allows the wound to heal without it becoming re-struck (NSW Agriculture 1999).

Immediate treatment of flystruck sheep is essential. Not only is the condition painful, affected animals may eventually succumb to blood poisoning and die.

NATIONAL WOOL DECLARATION

In 2008, the Australian Wool Exchange (through which around 90% of Australian wool is auctioned) introduced the National Wool Declaration (NWD) to allow woolgrowers to voluntarily declare the mulesing status of their sheep, and thus their animal welfare credentials, to wool buyers at auction (AWEX 2017b). Woolgrowers are asked to declare, on a mob basis, whether wool from that mob is from sheep that have not been mulesed (NM), whether some or all sheep have been mulesed (M), or whether all sheep were mulesed using pain relief (PR). If sheep are no longer mulesed on the property (and have not been for the last 12 months), then the grower declares 'ceased mulesing' (CM). Each of these categories attracts a premium per kilogram of wool sold at auction.

In 2016-17, a total of 1,709,686 bales of wool were sold at auction (AWEX 2017a). Of the bales offered that had mulesing status declared, 197,612 bales (12% of total) declared 'non mulesed' or 'ceased mulesed' and 426,385 bales (25% of total) declared that pain relief was used at mulesing (AWEX 2018b). The national percentage of bales with mulesing status declared was 65% as at 31 October 2017 with Tasmania and Victoria at the top declaring 85% and 79% respectively (AWEX 2018a). At that time, the percentage declared 'non mulesed' or 'ceased mulesed' was 12.7% and the percentage of bales declared that pain relief was used was 27.7% (AWEX 2018a). Even assuming that the remainder of bales, i.e. those without NWDs, had similar mulesing status declarations, considerably more work needs to be done towards achieving a phase out of mulesing and, in the interim, 100% uptake of pain relief.

Growing interest from wool buyers in mulesing status has seen a significant increase in premiums. As at 31 October 2017, national premiums for 'non mulesed', 'ceased mulesed' and 'pain relief' were 55c/kg, 76c/kg and 18c/kg respectively for 17 micron wool (AWEX2018a). Clearly and encouragingly, the market preference is for wool from sheep that are not (or no longer) mulesed. Interest is also rising in declaration status of all wool

(not just fine wool) as well as non-Merino wool, evidenced by discounts routinely being applied to bales that have not been declared (AWEX2018a).

Because the National Wool Declaration is voluntary, it is difficult to accurately track progress within the wool industry towards an end to mulesing and, in the interim, the extent to which mulesing is carried out with pain relief. It is the RSPCA's view that declaring mulesing status on the NWD must be mandatory. This would not only allow the wool industry to demonstrate their commitment to improving animal welfare and to provide transparency to the market and the opportunity for customers to make an informed choice but also provide stakeholders with the ability to monitor progress towards a long-awaited phase out of mulesing.

COMMUNICATION

Research on woolgrower attitudes towards mulesing and possible alternatives, showed that most believe that mulesing is more effective and more efficient (in terms of time, cost and effort) than any alternative (Wells et al 2011). Targeted communication with woolgrowers regarding breeding strategies that suit their sheep in their particular environment and their particular circumstances will likely promote better understanding of the breeding options available to growers. This knowledge as well as an awareness of the tools available to woolgrowers are more likely to encourage wider uptake of mules-free breeding strategies. A 2018 Merino woolgrower survey found that only around 50% of growers had visited the [FlyBoss](#) website (Sloane 2018). For woolgrowers to confidently move away from mulesing, greater awareness and application of the principles outlined in this and other decision-support tools is imperative. Australian Wool Innovation recently published key learnings from interviews with 40 wool-growing enterprises that have phased out mulesing (AWI 2018b):

- *“It is important to have a detailed plan in place before starting the move to a non-mulesed enterprise, that has the support of everyone in your business, including staff, contractors, shearers, livestock agents and ram suppliers.*
- *The business needs to be brave, organized and determined to make it work especially in the early years.*
- *Moving to a non-mulesed enterprise often requires fundamental change to the whole business.”*

The diversity of Australia's sheep population, its climate and its environment means the risk of flystrike is equally diverse. However, whatever the size and structure of the sheep enterprise, with the right attitude and the right management, a mules-free future for the Australian sheep flock is entirely possible.

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