FlyBoss: a web-based flystrike information and decision support system

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Abstract. The FlyBoss system consists of comprehensive information on flystrike management and control, programs for assisting decision making, and sortable lists of products for preventing and treating flystrike. Readily accessible, up-to-date, best-practice information on flystrike is essential for effective, humane and economic management of flystrike by Australian wool producers, particularly those who are phasing out mulesing and those looking to adopt optimal insecticidal fly-control strategies. FlyBoss provides information on breeding and management to reduce flystrike susceptibility, effective methods of treating existing flystrike and flystrike prevention programs. The FlyBoss decision aids, which are based on simulation models and incorporate local weather data and sheep susceptibility factors, can assist sheep farmers who wish to optimise sheep management, chemical treatment and non-chemical options to minimise the risk of flystrike. FlyBoss also contains comprehensive information on fly biology, sheep and environmental factors associated with flystrike and information on appropriate chemicals for various situations. FlyBoss draws on expertise from organisations throughout Australia to provide the sheep industry with easily accessible, current and locally targeted information on flystrike management. The present report briefly describes the development of FlyBoss and associated workshops and provides an overview of current recommendations for the control and prevention of flystrike.


Introduction

Flystrike is a major problem for Australian wool producers, costing A$280 million per year (Sackett \textit{et al. 2006}). Most sheep producers have developed a flystrike management system for their own property. This may include mulesing, and application of preventive treatment early in the fly season, or when a significant number of sheep are affected or when weather conditions increase the risk of flystrike (Horton and Champion 2001). There is a demand in some wool markets for wool from non-mulesed sheep. However, producers may have difficulty in predicting whether their current management system will confer sufficient protection against flystrike in the absence of mulesing.

Information and decision support systems on the control of internal parasites of sheep (van Wyk 2006; http://www.wool.com/Grow_WormBoss.htm, verified 1 October 2010) and sheep lice (Horton \textit{et al. 2007, 2008}; http://www.wool.com/Grow_LiceBoss.htm, verified 1 October 2010) are available. However, until the development of FlyBoss, information on flystrike management was scattered over a wide range of sources, few of which provided comprehensive information (McLeish \textit{et al. 2001}).

On-farm management of flystrike is complex, with many competing issues affecting sheep susceptibility. Although there are insecticides available for the prevention of flystrike, the excessive use of pesticides is discouraged (Shaw 1997). In many situations, chemical treatments can be avoided by astute management, provided wool producers are vigilant in monitoring their sheep for signs of flystrike (Horton and Champion 2001). Therefore, non-chemical management of flystrike is encouraged where possible. The timing of shearing and crutching are major factors in flystrike management (Campbell 2006) because the length of wool affects both flystrike risk and when chemical treatments can be applied.

The FlyBoss website (http://www.flyboss.org.au, verified 1 October 2010; Fig. 1) provides comprehensive information in a single location, together with decision support tools to assist producers who are considering changes in management that will affect flystrike control. Users can click on the six boxes to obtain more information under those headings.

The information module of FlyBoss was prepared from resources available on government agricultural websites, farmnotes and from scientific sources. Experts supplied additional information where necessary and the information was edited by a working group of flystrike experts to ensure that it was current and relevant. The working group decided which topics should be included in the FlyBoss website and how the subject matter should be arranged. Each member of the group then took responsibility for a specific topic. After all group members had reviewed all the topics, all sections were collated and the complete package was again reviewed. The present report does...
Factors which make sheep susceptible to flystrike

Long term breeding plans to reduce risk of flystrike

Annual management steps to reduce risk of flystrike

Methods available to help treat flystrike

Online risk assessment and planning tools

Contacts and newsletters to help provide assistance

Fig. 1. Home page of the FlyBoss website.
not describe all FlyBoss sections in detail, but considers some of the areas considered most critical.

**Susceptibility**

The susceptibility of a flock to breech strike is strongly associated with the degree of breech wrinkle and dags (Morley and Johnstone 1983). Excessive breech cover (Scobie and O’Connel 2010), yellow wool and urine stains also increase the risk of breech strike. The incidence of breech strike is low in sheep with a wrinkle score 1 or 2 (Australian Wool Innovation 2007) or a low dag score (score 1), and approximately doubles for each unit of wrinkle score >2 and for each unit of extra dag score (Greef and Karlsson 2009). Most breech strikes occur on sheep with high wrinkle scores or high dag scores.

The susceptibility to body strike can be decreased by reducing the incidence of fleece rot. Other factors that increase the susceptibility to body strike are lumpy wool (dermatophilosis), wool colour and structural conformation. A flock’s susceptibility to flystrike can easily be estimated using the standardised scoring system (Australian Wool Innovation 2007) for wrinkle, dags and fleece rot.

**Blowfly biology**

An understanding of the biology of the sheep blowfly is essential when developing a flystrike management plan. More than 90% of flystruck sheep are caused by the green sheep blowfly, Lucilia cuprina (Mackerras and Fuller 1937; Wardhaugh 2001). In most sheep-producing areas of Australia, flies survive winter as pre-pupaee in the soil. Therefore, flystrike only occurs in the warmer months. In warm weather, flies can develop into mature adults within 3 weeks. Each female lays an average of 180 eggs (Vogt et al. 1985), followed by another batch of eggs 4-8 days later (Wardhaugh 2001) and occasionally a third batch. Therefore, fly numbers may escalate rapidly if flystrike is not controlled and the weather is favourable.

During cool weather, larvae remain in the soil until spring, when they all emerge at about the same time in any given area. Newly hatched maggots lack mouthparts capable of abrading the sheep’s skin, but after the first moult (~18 h after hatching), they can aggravate the skin and cause severe wounds. They remain on the sheep only for a few days, but continual new flystruck flies will expand the lesion; therefore, frequent monitoring during the fly season is very important.

Warm, moist conditions favour flystrike activity and provide the predisposing conditions in sheep (Wardhaugh 2001). Triggers for flystrike usually relate to wet wool stained by urine or faeces for breech strike; fleece rot or mycotic dermatitis for body strike; puncture wounds from e.g. grass seeds, wounds from fighting or sweating around the horns, marking wounds or injuries or persistently wet wool. L. cuprina does not fly in strong winds and very hot, dry conditions in midsummer suppresses fly activity.

**Monitoring**

Flytraps are not usually a cost-effective means of reducing flystrike. At best, they may halve the incidence of flystrike (Ward and Farrell 2003), and the cost of flytraps is similar to that of jetting with insecticide, which provides a much greater reduction in strike incidence. However, flytraps may be useful for monitoring fly numbers, detecting the first appearance of flies in spring and identifying the places in which they are most prevalent on a property. Lucitrap™ are ideal for monitoring fly numbers because they contain LuciLureTM (Bioglobal Ltd, Wacol, Qld, Australia; Urech et al. 2001), which is specifically designed to attract L. cuprina rather than other types of flies. Carcases or liver are used as a fly attractant in bait bins, but these are not suitable for monitoring or reducing fly numbers because only ~5% of the flies trapped consist of L. cuprina (Heath and Leathwick 2001).

Young sheep should be monitored more closely than adults for flystrike, because sheep become less susceptible to flystrike with age. Ewes and wethers differ in susceptibility depending on the circumstances. If scouring occurs, then wethers may be at greater risk because of a smaller bare area, but if scouring it not present then ewes may have a greater risk of breech strike because of urine stain, whereas wethers are at risk of pizzle strike and rams have a high risk of poll strike.

**Geography**

Flies are less active in areas of native pasture or bush and more active in improved and irrigated pastures (Denwood et al. 1999; Horton et al. 2001). In general, paddocks that are more exposed to wind and have less ground cover, timber or wet areas will be safer for classes of sheep at high risk of flystrike, such as recently marked lambs, daggy sheep and lambing ewes. On many properties, some areas consistently have a higher flystrike risk. Wool producers will know these areas from experience. If possible, these areas should be avoided during periods of very high fly risk.

**Breeding and selection**

Genetic selection against fleece rot reduces susceptibility to body strike (Raadsma 1987) and selection against wrinkle score and dags reduces susceptibility to breech strike (Greef and Karlsson 2009; Scholtz et al. 2010). Selection for low breeze cover may also reduce strike (Edwards et al. 2009) and some sheep may have host defence mechanisms that restrict flystrike (Smith et al. 2008). Selection of appropriate rams and culling of sheep susceptible to flystrike are essential components of long-term flystrike management. Breeding and selection are not considered in detail here because they require more detailed consideration in a separate report.

**Management**

**Annual management plans**

It is advisable to review flystrike control practices regularly. All staff involved with the sheep enterprise should be familiar with the flystrike management calendar and should have the skills necessary to implement it. A management calendar should take into account shearing and crutching times, breech modification (if applicable), dag management, chemical application and breeding and selection. The FlyBoss Tools module can be helpful in designing and evaluating management calendars, as it identifies times at which there is a high risk of flystrike and predicts the effects of shearing, crutching and treatment at the specified times.

Fig. 2 is an example of flystrike risks for two theoretical shearing and crutching schedules for non-mulesed sheep at Glen...
Innes, a summer rainfall area. In one option, the sheep are shorn in October and are exposed to a single, long period in which there is a high risk of flystrike, which could be covered, if necessary, by a single application of a long-acting chemical treatment. In the second option, the sheep are shorn in December, leaving them exposed to two shorter periods in which there is a high risk of flystrike, namely before shearing and later in the fly season. Therefore, two applications of chemical treatment may be required to control flystrike, but the period for which protection is required is not as long as that required for the first option.

The National Wool Declaration
Some customers are requesting wool from non-mulesed sheep so it is important that all wool producers use the National Wool Declaration to describe the status of their wool as ‘mulesed’, ‘not mulesed’, from ‘properties that have ceased mulesing’ or ‘mulesed with pain relief’.

Each wool producer will need to make their own assessment of the market demand for different types of wool and their ability to manage flystrike with or without mulesing. However, it is recommended that producers use the declaration to allow wool buyers to identify the wool that meets product specification requirements.

The declaration also includes information on the risk of dark and medullated fibres and on chemical use, so producers who mules their sheep should use it even if the sections on mulesing are not relevant.

Shearing and crutching
Altering shearing dates is a non-chemical way of controlling flystrike and can reduce dependence on chemicals. However, there are many factors involved in the selection of shearing date other than flystrike. Moreover, shearing early in the fly season to reduce the risk of flystrike at that time may increase the risk of flystrike later in the season and vice versa. Shearing reduces the risk of flystrike because sheep with very short wool are much less susceptible to flystrike than those with long wool (Raadsma 1987). However, because protective chemicals are removed with the wool at shearing, the date of shearing should also be taken into account when planning chemical control strategies.

Because crutching reduces the length of wool in the breech and reduces the risk of dags accumulating, it reduces the risk of flystrike for ~2 months (Wardhaugh et al. 1989). Crutching can be done more often than shearing and it is easier to adjust the timing of crutching to reduce the risk of breech strike. However, the crutching schedule may be influenced by the need to reduce the amount of stained wool present at shearing or to clean up ewes before lambing. As protective chemicals are removed from the breech by crutching, the timing of crutching should be taken into account when planning chemical control strategies for breech strike. Non-mulesed sheep are more likely to become daggy and may need more frequent crutching or crutching at different times, and the crutching may be more difficult and slower than for mulesed sheep because of extra dags (Horton and Iles 2007) and wrinkle (Smith et al. 2010). Sheep with low breech cover will accumulate fewer dags and are less likely to be struck (Scobie et al. 2008; Scobie and O’Connel 2010), possibly reducing the need for frequent crutching.

Management of dags and scouring
If dags are present they are more of a flystrike risk than breech wrinkle. The risk of flystrike almost doubles for each unit increase in dag score (Greeff et al. 2010), as measured using the dag scoring system (Australian Wool Innovation 2007). Scouring increases costs because of the need for more frequent crutching and decreases wool income because crutching results in loss of fleece wool. Moreover, in addition to the increased risk of breech strike, potential income is lost through decreased body and wool weight and the additional treatment required when scouring is caused by internal parasites or bacteria.

The main causes of scouring are as follows:
- High worm burdens or numbers of larvae (Watts et al. 1978). This typically occurs in sheep less than 12 months old, but older sheep, especially ewes at lambing, may be affected.
- Bacterial enteritis and coccidiosis. These infections are most common in young sheep, particularly when they have high worm burdens.
- Hypersensitivity. This is caused by an inappropriate immune response to worm larvae, and is most prevalent in winter rainfall areas (Larsen et al. 1999; Larsen and Anderson 2000). Relatively low numbers of larvae may trigger this response.

![Fig. 2. Relative flystrike risk at various times of the year for non-mulesed sheep at Glen Innes, a summer rainfall site (dark solid line, sheep shorn in October and crutched in March; light dotted line, sheep shorn in December and crutched in June). It is not possible to predict actual numbers of strikes, so the vertical axis shows the relative risk at different times of the year using the specified management.](image-url)
FlyBoss: best-practice flystrike management

A detailed veterinary investigation may be required to identify the cause of scouring but a faecal worm egg count will indicate whether drenching is necessary or not. If the worm egg count is high, scouring will usually resolve, at least for a few weeks, after a drenching. However, hypersensitivity scouring responds poorly to short-acting drenches. Improved worm control may not prevent this form of scouring, but selection of rams (and ewes) for lower dag scores will eventually reduce the incidence of scouring. Sheep affected by hypersensitivity scouring have a genetic susceptibility to this inflammatory response.

The months in which scouring is likely to occur are usually predictable. Carefully conducted drenching helps control scouring in worm-prone areas, but resistance testing is required to determine which drenches are effective and worm egg counts are advisable to avoid unnecessary treatment. An effective worm control program is essential for flystrike management and information on the control of internal parasites is available at the WormBoss website (http://www.wool.com/Grow_WormBoss.htm, verified 1 October 2010).

Breech modification

Mulesing (Joint Blowfly Committee 1940) removes breech wrinkling and increases the bare area (non-wool-bearing skin) on the breech. Consequently, mulesed sheep are equivalent to non-mulesed sheep with wrinkled scores of 1 or 2 and low breech cover. Mulesing also reduces the tendency to accumulate dags (Horton and Iles 2007), which renders it a very effective means of reducing breech strike. Producers should not cease mulesing if they do not have a plan for reducing the risk of flystrike through alternative means such as selection against wrinkle score or an alteration to management practices.

If mulesing is part of the flystrike management strategy, it is recommended that an accredited operator be contracted to carry it out. Local anaesthetics can be used to reduce pain after mulesing, reduce bleeding and improve healing time (Lomax et al. 2009).

When tailing, dock immediately below the third joint because this enables the sheep to lift the tail well clear of urine or faeces, reducing staining around the breech and thus the risk of flystrike as well as reducing the risk of stained wool in the fleece.

Breech clips (Hemsworth et al. 2009) should only be applied by an accredited operator and can be removed for reuse 8–14 days after application. Clips are only about half as effective as mulesing (Lloyd et al. 2010) in respect of reducing wrinkle score and dags and increasing the area of wool-free skin, and therefore may not be adequate for all lambs.

Treatment

Chemicals

Chemicals are very effective in preventing flystrike and can be used to protect sheep during periods of high risk or when it will be difficult to monitor the flock. Most products provide protection against flystrike for ~3 months, but protection for ~5 months is possible with dicyclanil (Bowen et al. 1999). Some chemicals are applied as a low-volume backline spray-on, others as aqueous jetting solutions and some are available in both forms. Although dipping can be used, it is not recommended for flystrike.

Jetting

Hand jetting is more effective than using a jetting race but it is more time consuming if many sheep are to be treated (Lund and Levot 2001). A comparison of the advantages and disadvantages of each method is available at the FlyBoss website (http://www.flyboss.org.au/treatment/jetting.php, verified 1 October 2010). A jetting pump in which the pressure is maintained at 700 kPa should be used for jetting. The recommended jetting rate is usually 0.5 L per month of wool growth, subject to a minimum of 3 L per sheep. Sheep should be inspected to ensure that they are wet through to the skin, particularly if a jetting race is used (Lund and Levot 2001). The FlyBoss website contains a description of best-practice jetting using an automated jetting race and also videos on recommended methods for hand jetting and automatic jetting races (http://www.flyboss.org.au/treatment/jetting.php, verified 1 October 2010).

Spray-on chemicals

Some treatments are applied by spraying a low volume down the backline of the sheep in one or two strips, with an extra dose around the breech if required. The correct applicator must be used for each product and calibrated to ensure that the correct dosage is applied. For the prevention of body strike, the chemical should be applied over the full body length. If two or more bands are to be applied, they should overlap slightly. The FlyBoss website contains a video on the effective use of spray-on chemicals (http://www.flyboss.org.au/treatment/spray-ons.php, verified 1 October 2010).

Spray-on treatments are not suitable for sheep with existing flystrike or for sheep with soiled crutch areas. Sheep with dags should be crutched before treatment, but the chemical will last longer if applied ~6 weeks after crutching rather than immediately after crutching (James et al. 2009). Crutching alone will provide some protection for several weeks.

Treatment of struck sheep

Wool should be removed for a distance up to 5 cm around the flystrike wound to ensure removal of all maggots (Levot and Sales 1998) and to enable the lesion to dry out. If live maggots are present in the wool that is removed, the clippings should be sealed in a plastic bag and exposed to the sun or burned. A registered flystrike dressing should be applied to the wound to prevent repeat strikes (restrikes). However, many organophosphorus insecticide-based dressings have low effectiveness because of resistance, particularly against the third-stage (largest) maggots.

Sheep with flystrike should be isolated from the flock because they will attract flies to the flock and isolation allows closer monitoring during recovery. Unless very large numbers of sheep are affected, those that have had flystrike should be culled when they are fit for sale. Alternatively, they may be killed immediately, in which case the body should be disposed of appropriately to prevent the maggots from surviving. Burning is recommended if possible. The FlyBoss website contains a video on best-practice treatment of flystruck sheep (http://www.flyboss.org.au/treatment/treatment-of-struck-sheep.php, verified 1 October 2010).
Resistance

Resistance to chemical treatment can occur when larvae or flies are exposed to concentrations of chemicals that are insufficient to kill them all (McKenzie et al. 2001). Flies that are resistant to a specific insecticide will usually be resistant to other pesticides in the same chemical group. Resistance to one group of chemicals may also confer a degree of resistance to a different group of chemicals if the chemicals of the two groups are broken down via the same metabolic pathway (Levot 2001).

Resistance can occur when there is a high reliance on a single chemical group over many years (Levot 2001). Uneven coverage of the sheep with a chemical will increase the rate of development of resistance. Multiple generations of the flies per year, as with the sheep blowfly, increase the risk of development of resistance.

Development of resistance can be avoided by reducing the incidence of sublethal concentrations of pesticides (McKenzie et al. 2001). This involves always using the correct dosage and application method, taking into account that products used for lice control may also affect flies. Furthermore, it is important that protection lasts until flies are inactive (Levot 2001). Concentrations of chemicals in wool decrease over time after application because of breakdown and the diluting effect of wool growth (Horton and Campbell 2007). The FlyBoss Tools WoolRes module (Campbell and Horton 2002) contains estimates of the concentrations of chemicals in wool at various intervals after treatment.

Maggots from flystruck sheep should be disposed of in plastic bags or incinerated rather than relying on chemicals to kill them. Use of non-chemical control strategies and breeding to reduce strike susceptibility will minimise the development of resistance and reduce reliance on chemicals.

FlyBoss Tools

Flystrike decision support tools

A model was developed (Wardhaugh et al. 2007) for estimating the risk of flystrike in any given week based on weather conditions during the previous weeks. The model was developed using data collected over several years at Inverell, Gunning and Flinders Island from weather records and reports of flystrike from properties in these regions.

The flystrike risk model (Wardhaugh et al. 2007) was used to estimate flystrike risk for ~600 locations throughout Australia. The locations used were those with current weather records and at least 10 years of the measurements needed by the model (temperature, rainfall and humidity). All weather records for these locations were used to estimate the expected flystrike risk for each day for which records were available. Estimates of the average risk for each day of the year were calculated within regions using this data.

A FlyBoss module was then developed to estimate the risk of flystrike at any selected location in Australia, taking into account shearing time, crutching time and chemical treatment. With this program, it is possible to identify alternative times at which chemical treatment might reduce the risk of flystrike, without increasing the cost of treatment or changing shearing and crutching times.

A second FlyBoss module was developed to enable comparison of two alternative management strategies, e.g. comparison of alternative schedules for shearing or crutching, types of chemical treatments and the times at which they are administered, or alternative breech modification strategies such as mulesing versus not mulesing.

Product list

The FlyBoss product module was derived from the LiceBoss system (Horton et al. 2007) and consists of a list of the chemicals available for the prevention and treatment of flystrike.

The products list shows withholding periods that are applied to ensure that meat from treated sheep is fit for human consumption, that wool from such sheep is safe for processing and to protect the health of workers responsible for handling such sheep. The FlyBoss Tool module can be used to determine the appropriate time for treating sheep and the most effective product after taking the normal cycle of shearing and crutching into consideration.

WoolRes

The WoolRes program (Campbell and Horton 2002), which estimates pesticide residues in shorn wool for all registered chemical treatments, is included in the FlyBoss program. This module is similar to that contained in LiceBoss.

The FlyBoss Tools can be used to help time chemical applications or choose chemical products to minimise residues or meet particular residue targets.

More information

Industry training

This section of FlyBoss advises of the availability of flystrike management workshops held throughout Australia. Workshops on flystrike management were initially organised by Industry and Investment New South Wales. The presentations were reviewed by experts from all States to determine whether sections needed to be expanded, removed or modified for wider use. The presentation content was modified in accordance with these recommendations and reviewed again. Each State held separate workshops on the material and provided feedback to the working group on aspects that needed to be adjusted. For example, the prevalence of dags varies between regions. Therefore, the emphasis placed on dags and information on the causes of dags was adjusted according to region.

The aims of the workshops were to ensure that wool producers know about integrated approaches to flystrike management and that they will be able to manage the changes needed to decrease reliance on mulesing, have the skills to assess flystrike risk, use a suitable flystrike management plan and understand the importance of the National Wool Declaration.

It is important that wool producers understand the factors that render sheep susceptible to flystrike, can assess the risk of flystrike in their flocks (using the tools and information provided by FlyBoss), plan their breeding program (if applicable) to reduce flystrike, establish an annual management plan and treat flystrike effectively when it occurs, while ensuring that all animals are treated humanely.

Other information

The FlyBoss website includes recent press releases, newsletters relating to flystrike or mulesing, producers’ stories about flystrike
management, contact names for each State and links to relevant organisations and State Departments (http://www.flyboss.org.au/more-information.php, verified 1 October 2010).

Conclusions
The FlyBoss website provides comprehensive information on all aspects of flystrike management. It will be updated on a regular basis as new information is released or as new techniques or treatments become available. It is important that the expert review groups are maintained to ensure that new information is incorporated into the program.

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