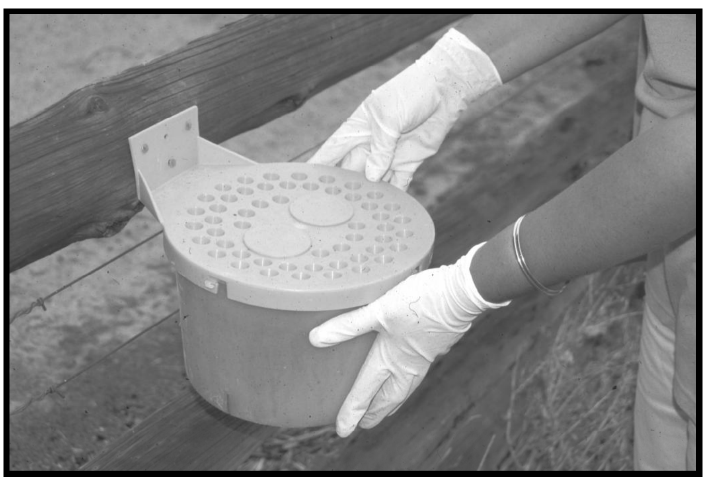
EVALUATION OF THE LARGE-SCALE TRAPPING OF BLOWFLIES (*Lucilia* spp.) FOR AN INTEGRATED PEST MANAGEMENT PROGRAM

THE LUCITRAP®



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DECLARATION

I hereby declare that the work in this thesis is my own original work and that it has not, as a whole or partially, been submitted for a degree at any other Technikon or University.

Signed: Date:

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PREFACE

The results presented in this dissertation have been partially presented at scientific meetings. Chapter 2 is an exact copy of the technical contents of a paper submitted to a scientific journal. The format of this paper however has been changed to comply with the format used in this dissertation. The results of this paper were partially presented at the *36th National Congress of the South African Society of Animal Science*, 5 – 8 April 1998 held in Stellenbosch. In this chapter errors occurred in the execution of the trial, but these were corrected in the follow-up trial after consulting with the manufacturers. It is discussed in the paper.

Results of chapter 3 were partially presented at the *5th International Sheep Veterinary Congress* 21 – 25 January 2001 held in Stellenbosch and at an International Congress (*The FLICS (Flystrike & Lice IPM Control Strategies) Conference*, 25 – 27 June 2001, Launceston) in Tasmania by Mr. S.W.P. Cloete in 2001. The updated results are given in this chapter.

The results of chapter 4 were presented at a combined congress between the Grasslands and the Animal Production Societies of South Africa (*The GSSA/SASAS Joint Congress 2002*. 13 – 16 May) in Christiana in 2002. The results in this chapter represent the same experimental period as was reported upon at that congress, but additional statistical analyses were executed on the same data set.

Copies of the abstracts of the contributions to these meetings are attached in chapter 6.

The major objective of this study initially was to evaluate the Lucitrap® system under South African conditions. During the experimental period I had an opportunity to visit Australia and meet many role players. It came under my attention that the control of the blowfly is a rather complex problem with many facets. A current issue worldwide on the use of chemicals as a control method against insects and its hazardous influence on the environment is forcing producers to minimize chemical residues in textiles and other agricultural products. An Integrated Pest Management (IPM) approach seems to be the only option. This study has been executed to try and understand some aspects of the blowfly problem for future application in such a blowfly control program.

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CHAPTER 1

GENERAL INTRODUCTION

In 1749 William Ellis published work on the management of sheep, in which he devoted a chapter to the question of "maggots that breed in the bodies of sheep and lambs." He gave a very interesting account of the sheep-fly, which is worth quoting.

> **"These sort of vermicular vermin are the death of many sheep and lambs, for as both these are very subject to breed maggots, by the blowing of several sorts of flies, and by the heat of the greasy wools in hot weather, they may be soon destroyed by maggots… These insects are so prone to multiply, that from their first increase they will kill a sheep in three day's time… A grievous malady indeed, that ought to be guarded against with the utmost vigilance, because part, or most of a flock, may, if neglected, be soon destroyed by maggots. And although this great evil is just touched on by ancient authors…. shall not so pass over the treating of these destructive vermin, but assure my reader, that sheep and lambs infected by them will infect others, by lying close in a fold or elsewhere to one another. Now the sheep and lambs that are most liable to the breed of maggots are those that carry the most and closest wool on their backs; the more they are frequently heated by driving them out of their natural walk the sooner they come under the misfortune" (as cited by Carpenter, 1902).**

Carpenter (1902) made a statement applicable to sheep-breeders all over the world.

> "**It seems that, over a limited area, one or two kinds of flesh-flies have forsaken the usual habit of their family, so that the maggots have become parasites instead of scavengers. There can be no doubt that this change of habit has been induced by the domestication of sheep by man. We have taken an originally alphine race of animals,**

> **crowded them on the plains, and by artificial selection increased the qualities – such as fat and thick wool – that tend to attract the fly.”**

Zumpt gave a clear explanation of myiasis in (1965) as:

> **“the infestation of live human and vertebrate animals with dipterous larvae, which, at least for a certain period, feed on the host’s dead or living tissue, liquid body substances, or ingested food”**

Blowfly strike (ovine myiasis) is the cutaneous infestation of sheep by the larvae of blowflies (French *et al.*, 1992). The adults are free-living and the larvae are parasitic maggots, which develop in the tissue of their host (Howell *et al*., 1978). In the spring, the larvae begin post-diapause development, leading to pupation and adult emergence (Wall *et al.*, 1992a). The free flying adult females deposit their eggs in the wool of sheep close to the skin surface, commonly selecting areas soiled by faeces and urine or near sores or open wounds (Davies, 1948; Cragg, 1955). The larvae invade the sheep’s skin using both mechanical and enzymatic digestion (Constable, 1994). In the case of *Lucilia cuprina*, first instar larvae do not have well-developed mouthparts (Sandeman *et al.*, 1987) and feed mainly on the serous exudate at the skin’s surface (MacKerras and Freney, 1933). In contrast, the second and third instars possess well-developed mouth hooks that help them to invade flesh tissue (Sandeman *et al.*, 1987). The feeding activity of the larvae causes extensive tissue damage and leads to considerable distress to the struck animal, reduced weight gain, loss of fertility (Heath *et al.*, 1987) and, if untreated, rapidly leads to death from chronic ammonia toxicity (Guerrini, 1988). On completion of feeding, third instar larvae migrate away from the strike focus, dropping to the ground to pupate (Wall *et al.*, 1992a).

Blowflies are important parasites of sheep (Howell *et al*., 1978) and other domestic stock and occur in many of the major sheep-producing countries in the world (French *et al.*, 1992). The control and loss of production caused by flystrike results in major expense for sheep production in the world. In South Africa, blowfly strikes resulted in an estimated annual loss of R19.8 million in the small stock industry (Leipoldt and Van Der Linde, 1997). Furthermore flystrike causes animal welfare problems, which may ultimately impact on our ability to market sheep products (Zumpt, 1965; Cottam *et al*., 1998).

Zumpt (1965) reported *L. cuprina* to be the principle fly involved in myiasis of sheep in South Africa while it also causes myiasis in other African countries and in India. Howell *et al.* (1978) and De Wet *et al*. (1986) confirmed this by reporting that the Australian blowfly, *L. cuprina* is responsible for almost all primary strikes in South Africa. *Lucilia sericata* has also been reported to be responsible for strikes on live sheep in South Africa (Smit and Du Plessis, 1927). Erzinclioglu (1989) reported that the blowflies, *L. cuprina* (Wiedemann) and *L. sericata* (Meigen) are probably the two most important blowflies responsible for sheep myiasis in the Southern Hemisphere. In Australia *L. cuprina* are responsible for 90% of flystrike (Monzu and Mangano, 1984; Anderson *et al*., 1988) and is estimated to result in the death of 3 million sheep annually (Breadmeadow *et al*., 1984; Wardhaugh and Morton, 1990). Which is further supported by MacKerras and Fuller, 1937; Watts *et al*., 1976; Murray, 1978; Barton, 1982 and McQuillan *et al*., 1984 confirming that *L. cuprin*a is the primary myiasis fly of sheep in Australia. Although *L. sericata* has an impact on sheep production, it is generally regarded as of minor importance in Australia (Watts *et al.*, 1976). In Britain however, *L. sericata* is regarded as the primary agent of cutaneous myiasis in sheep (MacLeod, 1943a; Tenquist and Wright, 1976; Wall *et al*., 1992a,b).

Both species (*L. cuprina* and *L. sericata*) are carrion-breeders and facultative parasites (Erzinclioglu, 1989). Although these species are attracted to carrion, they rarely breed successfully in carrion due to intense competition from native calliphorids for the food source (Waterhouse, 1947). It has also been reported that blowflies changed their behavior from living predominantly on carcasses, to being ecto-parasites, living on live sheep (De Wet *et al*., 1986). This is supported by Anderson *et al*. (1988) reporting that the population maintenance of *L. cuprina* in the arid regions of Australia is achieved entirely through flystrike and that this fly is therefore an obligate parasite of live sheep in those regions.

It is not certain when the blowfly problem emerged in South Africa, but strikes increased at the beginning of the previous century and the problem evolved with the Wool industry (De Wet *et al*., 1986). It is not clear how or when the Australian sheep blowfly became established in Australia. *Lucilia cuprina* is thought to have arrived in Australia from South Africa as early as the mid- to late- 19th century (Norris, 1990). It seems most likely to have been introduced into the eastern States from South Africa or India. It subsequently spread from there across Australia (Monzu, Bulletin 4101). *Lucilia cuprina* was recognized as a major pest of the sheep industry in Eastern Australia by 1915, in Western Australia by the late 1930's and by the late 1950's in Tasmania (Monzu, Bulletin 4101).

It is reported that *L. sericata* arrived over 100 years ago in New Zealand (Miller, 1939) and it is widely distributed in the North and South Islands (Dear, 1986). The species *L. cuprina* had been intercepted in imported cargo several times prior to 1986, but Dear (1986) was of the opinion that it was unlikely to establish in New Zealand (Holloway, 1991). It is believed that *L. cuprina* became established in New Zealand since the late 1970's but that it was only reported in 1988, when its presence was confirmed throughout most regions of the North Island (Heath, 1990; Heath *et al.*, 1991). Cottam *et al*. reported in 1998 that *L. cuprina* was the dominant strike initiator in New Zealand, although *L. sericata* was the species most prevalent in trap catches.

Sheep are not struck by chance or haphazardly: the susceptibility of an animal to blowfly strike depends on the presence of moisture in the fleece, with resulting bacterial decomposition of the wool and superficial skin layers known as "fleece-rot" (Howell *et al.*, 1978). Breech strike and strikes to the back, flanks or withers (body strike) are the two forms of myiasis of greatest concern (Watts *et al.*, 1979; Murray, 1980; Barton, 1982). Sheep are struck most frequently in the breech and around the tail where the wool is soiled by faeces, or by urine in the case of ewes (Howell *et al*, 1978). French *et al*. (1995) reported that the contamination of wool with urine and faeces create important local areas of high humidity, making it very attractive for strikes. MacLeod (1943b) identified wool length as the factor dominating sheep susceptibility to blowfly strike. The odour arising from such areas of decomposition attracts the flies and also provides a suitable habitat for the young larvae to thrive in (Howell *et al.*, 1978). Body strike is strongly weather dependent (Hayman, 1953) and is it usually associated with the development of fleece rot (Belschner, 1937) and/or mycotic dermatitis (Gheradi *et al.*, 1981). In the case of body strikes, deep skin folds, which cause a "sweaty" condition, and infected body wounds, tend to attract flies (Howell *et al*., 1978).

Until now blowfly control has largely relied on prophylactic measures based on the use of insecticides (Howell *et al*., 1978). Alternative methods of control that have been investigated in Australia, includes eradication of the major primary strike species, *L. cuprina*, using genetic control (Whitten *et al.*, 1977, Mahon, 2001). Vaccination against larval infection (O'Donnell *et al.*, 1980, 1981) and vaccination against fleece conditions that predispose sheep to strike (Sandeman *et al.,* 1985; Sandeman *et al.*, 1986; Sandeman, 1990) has also been investigated. Other methods of control include removing soiled wool from the breech of the sheep (dagging or crutching; Graham *et al*., 1947), tail amputation (docking; Graham *et al*., 1947) and the prompt disposal of carcasses (French *et al.*, 1992). Reducing urine and faecal staining, by the surgical removal of wool bearing skin from the crutch area (Mule's operation; Bull, 1931), is also used to prevent breech strike (Steiner and Harrington, 1997). A new product Spinosad (a natural product registered as Extinosad®) has very low mammalian toxicity, is safe for shearers and operators and is relatively safe to the environment (Crouse and Sparks, 1998). This product breaks down quickly in the wool (Russell *et al*., 2000) leading to low wool residues but a briefer protection period against re-infestation than more persistent molecules. This characteristic makes it very useful in sheep with long wool where other products leave unacceptable wool residues at shearing time (Rothwell *et al*., 2001). This product is thus extremely useful when used tactically in the face of a flywave in long wool sheep.

Blowfly strike was very successfully combated using chemicals for many years. Eventually insects started to develop resistance to commonly used insecticides (Gleeson *et al.*, 1994; Wilson and Heath, 1994; Levot and Barchia, 1995). Concern about the residue implications of pesticide use in the meat trade during the mid 1980's led to the realization that harvested wool also contained pesticide residues. The then Australian Wool Corporation (now The Woolmark Company) began a regular program of monitoring residue concentrations in the Australian wool clip (Savage and Russell, unpublished). The veterinary chemical industry as well as some growers and their advisors, would argue that residues are necessary to give adequate long term protection from insect pests (Savage and Russell, unpublished). However, a recent study undertaken in Australia for the Woolmark Company by the National registration Authority for Agricultural and Veterinary Chemicals (NRA) has identified a number of potential problems associated with these residues, including:

- "the possible occupational hazard of residues to farm workers handling treated sheep (for example during crutching), and shearers and other workers handling harvested wool;
- the impact of residues in scouring effluent on the environment, as most of the residual pesticide is removed from the wool fibre by the scouring process and discharged into the environment in some form of scouring effluent;
- the impact of residues on the trade of Australian raw wool (about 60% is scoured overseas), particularly in a trading environment where processors are demanding low residue wool because tough environmental restrictions on scouring effluent and a growing consumer demand for "eco-wool" (defined as wool produced in an environmentally sustainable manner" - Savage and Russell, unpublished).

A potential trade issue has been driven by the European Union's (EU) decision (October 1996) to adopt the Integrated Pollution Prevention and Control Directive (IPPC). This Directive is of concern because it forms only one part of a matrix of legislation that will be applicable throughout all of the EU (Madden, 2001). It further builds on and widens the present United Kingdom (UK) environmental requirements (Savage and Russell, unpublished). Madden (2001) reported that the legislation does not just apply to wool or to textiles, but also to all manufacturing, and to all product stages, from raw material to the disposal of the manufactured product at the end of its life cycle. Savage and Russell (unpublished) confirmed this by reporting that this legislation requires that controlled installations (such as wool scours) use the best available technology that is economically feasible to reduce emissions to the environment, and to demonstrate that their emissions cause no environmental harm. It reflects a comprehensive 'greening' of Europe, and this is a trend that South African and Australian wool producers cannot afford to ignore (Madden, 2001). This means that UK and EU wool scours will need to meet risk-based environmental requirements that are much stricter than those presently operating in Australia or South Africa. Other overseas countries are expected to follow the EU precedent. This has prompted the International Wool and Textile Organization (IWTO - the peak international wool trading and processing body), to explore options for testing wool for pesticide content prior to sale (Savage and Russell, unpublished). This is going to have major implications on the South African exporting of wool.

When seen against this background, sustainable ectoparasitic control/eradication is an important aim for the entire sheep industry (Karlsson, unpublished). The latter author furthermore reported that the most efficient method to achieve this aim is through integrated pest management (IPM) programs. It is clear that the recent move towards pesticide residue minimization favor an IPM approach.

Integrated management, including the strategic use of insecticides when strike is imminent, seems to be the farmer's most effective means of controlling bodystrike (cf. breech strike) (Steiner *et al.*, 1994). Farmers are being encouraged to adopt curative treatment of strikes rather than prophylactic jetting of whole flocks, to control flystrike (Wardhaugh and Morton, 1990; Levot and Sales, 1998). Levot (2001) also enforces that the control of sheep ectoparasites currently relies on an integration of sheep husbandry, farm management and insecticide use. Alternative means of fly control for integration with existing control procedures are urgently needed (Cottam *et al*., 1998). This has generated interest in the investigation and development of alternative, localized control strategies with emphasis on reducing the reliance on pesticides (Gleeson and Sarre, 1997). According to French *et al.* (1992), the control of blowfly strike is aimed at reducing the fly population as well as a reduction in the susceptibility of sheep. One component in such an IPM program can be the use of blowfly traps to reduce the blowfly challenge.

The need to minimise insecticide usage, either through the more timely application of chemicals (Monzu and Mangano, 1984; MacKenzie and Anderson, 1990) or through the development of alternative, non-chemical methods of control has stimulated new research on the population dynamics of *L. cuprina* (Wardhaugh, 2001). Gleeson and Heath (1997) studied the population biology of *L. cuprina*, finding that one of the major contributors to fly migration between regions is the movement of infested sheep rather than movement of the flies themselves. This research demonstrated that *L. cuprina* has a low tendency for dispersal when favourable habitat conditions exist. Gleeson and Heath (1997) further reported that these results suggest that localised control measures such as large-scale trapping and genetic control techniques may have potential for controlling *L. cuprina* numbers, while reducing the reliance on insecticide usage. Foster *et al*. (1975) reported that flies released as pupae within a favourable habitat spread on average only 1.2

km in 48 hours and 1.6 km in 9 days upon emergence, however most flies remained within a 1km radius of the emergence site. Flytraps are used for monitoring purposes, for ecological studies and in a few cases for population control. The development of flytraps spans a period of many decades (Hutchinson, 1997). The use of flytraps to control and occasionally eradicate certain fly species has its origins set in the last century. A kerosene lamp was available in 1866 in America for use against synanthropic dipterans (Hutchinson, 1997). Serious work on flytraps however did not truly begin until insect pests developed resistance to insecticides such as DDT **(**Dichlorodiphenyltrichloroethane), Dieldrin and BHT, which was mainly facilitated by the over spraying of agricultural crops (Hutchinson, 1997).

Flytraps have been used in the Australian sheep industry for many years (Ward and Farrell, 2000). Numerous modifications of the "West-Australian" flytrap - first described by Newman and Clark (1926) - have been made over the years. In 1936, MacKerras *et al.* described a bait bin, based on liver and sodium sulfide that reduced blowfly strike by up to 50%. This general approach was still being used in the 1980's (Anderson *et al*., 1990). Even though these traps apparently reduced flystrike, a constraint to their use was the amount of labor needed to regularly service the traps (Ward and Farrell, 2000).

In the early 1990s, a synthetic lure was developed specifically to attract *L. cuprina* (Urech *et al*., 1993). A trap system, based on this lure, was released commercially in Australia in 1994 as Lucitrap® (Miazma, Pty. Ltd. Mt. Crosby, Queensland, 4306, 1994) (Anonymous, 1994). Ward and Farrell (2000) reported that (unlike bait bins), this system requires minimal ongoing labour input, and that the synthetic lures used in this system appear to be more attractive to and specific for *L. cuprina*. Initially this system was found to be effective in reducing blowfly populations at two Queensland localities (Urech *et al.*, 1996). The subsequent study was extended to cover 21 trials in five Australian states over three summers (Urech *et al.*, 1998). Suppression of the blowfly population, amounting on average to 77%, was achieved in 62% of these trials. In Tasmania these flytraps were most effective in sites near water, exposed to the sun, sheltered from the wind and attached to posts rather than to trees (Horton *et al*., 2001). Improvements to this trap by increasing the shelf life of Lucilure® from four months to at least two years and by making use of a more transparent bucket makes it a more attractive component of any control strategy for sheep blowflies (Urech *et al*., 2001).

An important factor to consider in monitoring fly populations is how the numbers of the flies caught relate to incidence in flystrike in sheep flocks (Cottam *et al.*, 1998). Trap efficiencies vary due to differences in the needs of each fly species and to needs of different cohorts within a species (Heath, 1994). The incidence of flystrike was found to increase with an increased density and activity of gravid *L. cuprina*, with rainfall determining the overall strike levels (Wardhaugh and Morton, 1990). The abundance of primary blowflies present in an area may determine the severity and number of strikes seen, but there is a tendency for the condition to occur seasonally (Howell *et al*., 1978). In South Africa the appearance of the first wave of blowflies generally coincides with the first rains in spring in summer fainfall areas when adult flies emerge from the thousands of pupae in the soil (Howell *et al*., 1978). During the warm summer months fly numbers generally decrease until autumn, when a second wave may be produced (Howell *et al*., 1978). Heath (1994) recommended that farmer's install an "early warning" system using simple flytraps to monitor fly numbers and detect the emergence of blowflies. Carrion-baited traps have been used in many studies to sample field populations (Vogt *et al.*, 1985; Dymock and Forgie, 1995). Wind-oriented traps designed in Australia were used to study the effects of other variables such as height of trap, duration, and timing of trapping on the blowfly species composition that was collected (Dymock *et al.*, 1991). Data on fly abundance, flock management and weather conditions is not only a prerequisite for rationalizing insecticide usage, but it is also essential for assessing the potential benefits of alternative control strategies based on fly suppression (Wardhaugh and Morton, 1990).

Against this background, it was reasoned that the Lucitrap® may be of benefit for the South African sheep industry. The purpose of this thesis was to evaluate the effectiveness of the trapping system for the suppression of sheep blowfly numbers, as well as the selectivity of the trapping system for *Lucilia* spp. under South African conditions. Data on relationships between the yield of a Lucitrap® and climate were also obtained, to broaden the current knowledge on fly biology and population dynamics.

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CHAPTER 2

A PRELIMINARY EVALUATION OF A SHEEP BLOWFLY TRAP IN THE WESTERN CAPE

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ABSTRACT

An insecticide-free sheep blowfly trapping system, utilising a synthetic lure, was evaluated at four localities in the Western Cape. Control sites, where no suppression was practised, were identified for each locality. The blowfly population was monitored for 48 hours monthly at each of the localities. Five to seven suppression traps at the respective localities were identified for this purpose. Three to ten traps were set monthly for monitoring in the control areas. Trapping resulted in the suppression ($P < 0.01$) of the *Lucilia* population at Caledon, where a large area of approximately 50 km^2 was trapped. The suppression area of all the localities was $\leq$ 850 ha. At Elsenburg, blowfly numbers were low. There was a strong suggestion of a general reduction in the *Lucilia* numbers at this locality. Trapping failed to reduce *Lucilia* numbers at Tygerhoek and Langgewens. Lack of control over the influx of *Lucilia* from adjacent sheep - producing areas probably contributed to this result. The observed response at Elsenburg was probably due to its situation in a predominantly wine-growing area. Most of the blowflies recovered from the control traps during the month with the highest yield at the respective localities belonged to the genus *Lucilia*. The results obtained at Caledon and published reports suggest that large-scale trapping of *Lucilia* spp. may play a role in an integrated pest management system for blowflies.

Keywords: Blowfly, flystrike, trapping, woolled sheep.

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INTRODUCTION

Blowfly strikes result in an estimated annual loss of R19.8 million to the South African small stock industry (Leipoldt and Van der Linde, 1997). The blowfly *Lucilia cuprina* is responsible for almost all primary strikes (Howell *et al*., 1978; De Wet *et al.*, 1986), while *Lucilia sericata* has also been reported to be responsible for strikes on live sheep in South Africa, the United Kingdom and

New Zealand (Smit and Du Plessis, 1927; Miller, 1939; MacLeod, 1943; Atkinson and Leathwick, 1995;).

Chrysomyia chloropyga is also responsible for a small percentage (about 10%) *of* primary strikes (Howell *et al*., 1978; De Wet *et al.*, 1986). Blowfly control largely relies on insecticides (Howell *et al*., 1978; Hughes and Levot, 1987). Strains of *L. cuprina* have demonstrated an ability to develop resistance to these chemicals (Fiedler and Du Toit, 1956; Hughes and McKenzie, 1987; Gleeson, *et al.*, 1994; Wilson and Heath, 1994; Levot and Barchia, 1995; Wilson *et al.*, 1996). International trade agreements increasingly strive to control harmful chemical residues in products. It was evident that pesticide residues in wool were highly variable and difficult to predict accurately in Australia (Plant *et al*., 1999). It is thus almost impossible to estimate the risk of contamination of batches of wool with an acceptable degree of accuracy. Alternative means of control include the removal of breech skin folds by the Mules operation (De Wet *et al*., 1986), the destruction of carcasses and better hygiene (French *et al*., 1992), but these practices on their own are usually not sufficient for complete blowfly control. Alternative measures therefore need to be assessed to manage this problem in an integrated manner, resulting in a more sustainable approach. An Australian–developed insecticide–free trapping system (using a synthetic attractant) for *L. cuprina*, may benefit the South African sheep industry. This system was found to be effective in reducing blowfly populations at two Queensland localities (Urech *et al*., 1996), and the study was extended to cover 21 trials in five Australian states over three summers (Urech *et al*., 1998). Suppression of the blowfly population, amounting on average to 77%, was achieved in 62% of these trials. No conclusion could be drawn in 24% of the trials, owing to very low fly counts during very dry conditions.

In the current study the effectiveness of the trapping system for the suppression of sheep blowfly numbers was evaluated, as well as the selectivity of the trapping system for South African *Lucilia* spp. Preliminary findings are presented in this report.

MATERIAL AND METHODS

Traps and locations

The commercial brand of trap used was the Lucitrap® system (Anonymous, 1994; Urech *et al.*, 1996; Urech *et al.*, 1998). A synthetic attractant served as lure to entice blowflies to enter the trap. Once inside the trap, flies find it difficult to escape and die of dehydration and starvation (Anonymous, 1994). No insecticide is required.

One trap per 100 breeding ewes was set in sheep paddocks, as prescribed by the manufacturer (Anonymous, 1994). These traps were set before the expected rise in the blowfly population during early spring. Since usage of Lucitrap® mostly resulted in a reduction of the blowfly population (Urech *et al*., 1996; Urech *et al*., 1998), these areas are referred to as suppression areas. The blowfly populations in four suppression and neighbouring control areas (described later) were monitored monthly. For this purpose, identified suppression traps were cleaned and left open for a period of 48 hours during the first week of every month. This method of monitoring in the suppression areas differed from that employed by Urech *et al*., 1996; Urech *et al*., 1998, in that a separate set of traps was employed exclusively for monitoring purposes and was only baited for a 48 hour period each month. After 48 hours, a contact insecticide was sprayed into these traps before the contents were recovered, and preserved in 70% alcohol for counting. Blowflies were separated according to species (Howell *et al*., 1978) and counted. The blowfly species identified were *L. cuprina*, *L. sericata*, *Chrysomyia albiceps* and *C. chloropyga*. Separate sets of traps were used to monitor blowfly populations in adjacent control areas. Apart from being removed after each 48 hour - monitoring period, the treatment and sampling of these traps were carried out as described previously. In the study of Urech *et al*., 1996; Urech *et al*., 1998, control areas were monitored by a permanent set of traps that were baited for a 48 hour period every month.

Trapping system used at four localities in the Western Cape:

Caledon: An area of approximately 50 km^2 was identified for suppression. The area was situated approximately at latitude 34° 16’ S and longitude 19° 42’ E.

The suppression area was situated in the foothills of the Swartberg Mountains. The topography of the site is sloping, with valleys draining in the south - westerly direction. The average annual precipitation is 420 mm, of which approximately 70 % is recorded between April and September. It is situated within the cropping-pasture regions of the Southern Cape, and the most important farming ventures are small grain cropping as well as mutton and wool production. The area supported approximately 4000 breeding ewes, mostly Merinos. In total, 34 suppression traps were set in this area in mid - September 1997. Five of these, near to the centre of the suppression area, were used to monitor the blowfly population.

Two nearby (approximately four km) farms within the same agro-ecological region, supporting approximately 1000 Merino breeding ewes, were identified as the control area. The blowfly populations were monitored with five traps on each property. Data for this location were available from October 1997 to March 1998. As the monitoring traps in the control area were only set for the first time during November 1997, no data were available for the control area during October 1997.

Tygerhoek: The Tygerhoek Experimental farm (± 800 ha, at 34°08' S and 21° 11' E, altitude 425 m) near Riviersonderend was used as the second suppression area. The long-term rainfall at the locality was estimated at 429 mm, 60 % of which is usually expected between April and September. This site is also situated in an area where small grain cropping and sheep farming for wool production are the dominant farming enterprises. The farm supported 700 Merino breeding-ewes. Seven suppression traps were set during mid-September 1997 and used to monitor the blowfly population as well.

The control area was identified at a nearby property, and three traps were used to monitor the blowfly population monthly. This farm supported approximately 800 breeding-ewes, mostly merinos. The data for this location were collected during the period October 1997 to June 1998.

Langgewens: The third suppression area was the Langgewens Experimental Farm of ± 500 ha, (33° 17' S and 18° 42' E, altitude 177m), about 20 km north of Malmesbury in an area known as the Swartland. The long-term rainfall at the locality averaged 395 mm. As expected with a Mediterranean type of climate, 78% of the precipitation occurred between April and September. The locality is also situated in a typical small grain and sheep-farming region, with wheat cropping as the dominant farming venture. Wool- and dual-purpose sheep farming are also considered to be important enterprises. The farm carried approximately 600 breeding ewes, 200 Merinos and 400 SA Mutton Merinos. Six traps were considered adequate for the suppression of the blowfly population, suppression commencing at the end of August 1997. The same traps were used to monitor the blowfly population.

A nearby property was identified as the control area, and three traps were used to monitor the blowfly population monthly. This property supported about 2000 Dohne Merino sheep. Data were available from October 1997 to May 1998.

Elsenburg: The fourth location was identified as the Elsenburg Experimental farm (± 850 ha, 33° 51' S and 18°50' E, altitude 177m), about 10 km north of Stellenbosch. The average long-term precipitation here was 606 mm. The climate is Mediterranean, with 77 % of the total rainfall being recorded from April to September. The site is situated in the horticultural areas of Stellenbosch, and the dominant farming enterprise is viticulture. The major livestock enterprise is dairy production. Sheep are kept on only two other properties in the vicinity. The suppression area supported approximately 600 breeding ewes, about 200 Merinos, 250 SA Mutton Merinos and 150 Dormers. Six traps were regarded as adequate for the suppression of the blowfly population, starting at the end of August 1997. The same traps were used for monitoring.

One of the nearby properties where sheep were kept was identified as the control area. A flock of 250 Dohne Merino ewes were run on this property.

Three traps were used for monthly monitoring of the blowfly population. Data for this location were available for the period from October 1997 to June 1998.

Routine management strategies, representative of those applied in the rest of the region, were followed on the farms included in the study for the experimental period. These involved the spot treatment of strikes where appropriate, as well as preventive treatment when an increase in blowfly numbers was expected. Non-insecticidal protective agents like Vetrazin® (Cyromazine, Novartis Animal Health) were sometimes used. These strategies were broadly similar in the suppression and control areas, and were unlikely to have influenced the results of this study. It was decided to use data from the control areas to indicate the selectivity of the traps for specific blowfly species, on the assumption that the population could have been altered in the suppression areas (Urech *et al.*, 1996; Urech *et al.,* 1998). The month with the highest yield at each locality was used for this purpose, in order to assess the selectivity of the traps with the highest counts possible.

Statistical methods

The effect of suppression on the *Lucilia* populations of the respective localities was assessed in factorial analyses, incorporating the effects of the designation of the trap (located in a suppression or in a control area) and month. Months included in the analyses were October 1997 to March 1998 for Caledon, October 1997 to May 1998 for Langgewens and October 1997 to June 1998 for Tygerhoek and Elsenburg. The *Lucilia* spp. (*L. cuprina* and *L. sericata*) was pooled for these analyses. Data for the four localities were analysed separately, as the responses obtained appeared to differ. *Lucilia* counts for trap months were extremely variable, ranging from 0 to 1032 (overall mean ± *SD* across localities = 41 ± 96). In order to normalise the distribution, the $\log_{10}$ was calculated for the *Lucilia* count +1 (to account for zero counts) yielded by individual traps before statistical analysis.

The selectivity of the traps was evaluated using four localities x three blowfly species (*L. cuprina, L. sericata, Chrysomyia* spp.) in a preliminary analysis. Only the months with the highest *Lucilia* yield in the control areas were considered. The two species of the genus *Lucilia* were pooled in the final analysis, resulting in a 4 x 2 factorial design.

RESULTS

Monthly *Lucilia* yield in the suppression and control areas

In Caledon there was no indication that counts in the suppression or control areas reacted differently to influences specific to the months included in the investigation. The interaction between the designation of the trap and month was thus not significant ($P > 0.05$; Fig. 1). In general, the traps used for monitoring purposes in the control area yielded higher *Lucilia* numbers than those in the suppression area (respective $\log_{10}$-transformed means and standard errors when pooled across months were 1.41 ± 0.10 *vs.* 0.99 ± 0.11; respective geometric means 26 *vs.* 10; $P < 0.01$).

At Tygerhoek, no significant interaction was similarly observed between the designation of the trap and month (Fig. 2). No difference in *Lucilia* numbers was observed between traps in the suppression or control areas (respective overall $\log_{10}$-transformed means and standard errors when pooled across months were 1.21 ± 0.11 *vs.* 1.29 ± 0.07; respective geometric means 16 *vs.* 19; $P > 0.50$). Significant ($P < 0.01$) month effects suggested peak activity during October/November 1997, and again during February/March 1998, with lower levels of activity during January 1998 and during the cooler months (April to June 1998).

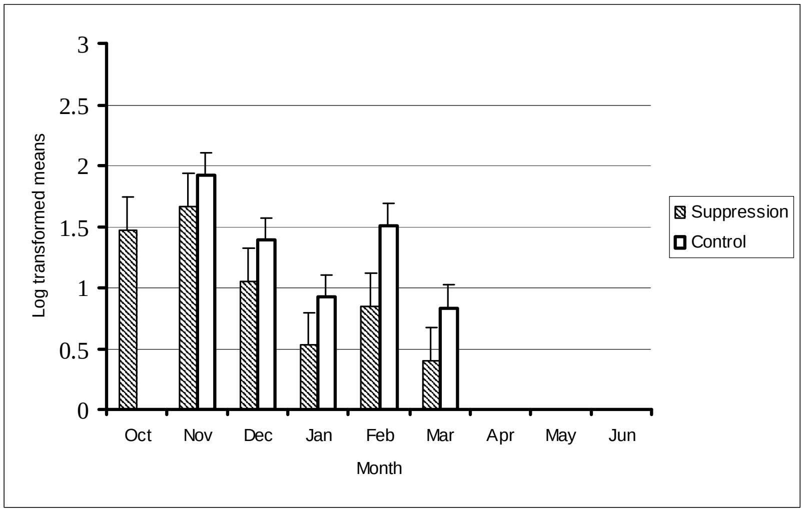

Figure 1. Mean log_{10} transformed *Lucilia* counts collected over a 48 hour period in the suppression and control areas of Caledon. The vertical lines upon the hatched column represent standard errors.

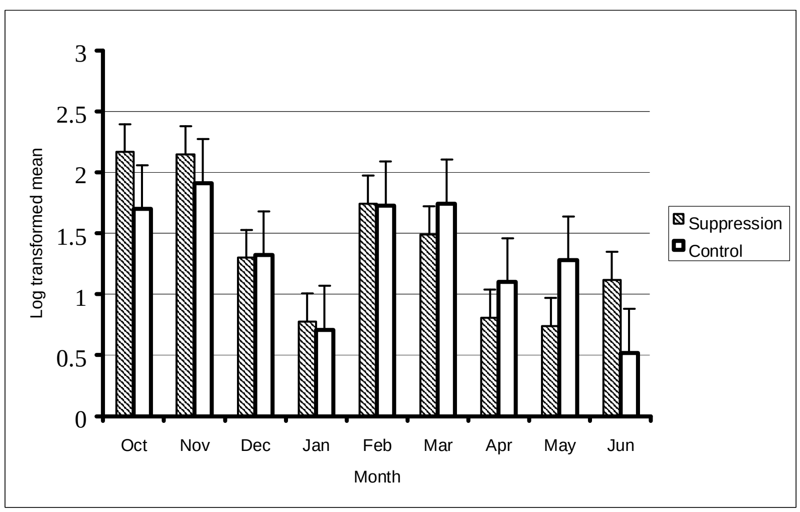

Figure 2. Mean log_{10} transformed *Lucilia* counts collected over a 48 hour period in the suppression and control areas of Tygerhoek. The vertical lines upon the hatched column represent standard errors.

The *Lucilia* population at the Langgewens locality declined from the log_{10} transformed mean (± *SE*) of 2.09 ± 0.16 (geometric mean = 123) during October 1997 to 0.13 ± 0.16 (geometric mean = 1) during May 1998 (Fig. 3). Responses to the respective months in the suppression and control areas were largely similar (*P* for the interaction = 0.20). Overall, the traps in the suppression areas yielded slightly higher *Lucilia* numbers than those in the control areas (respectively $\log_{10}$ transformed means and standard errors were 0.92 ± 0.06 *vs.* 0.67 ± 0.09; respective geometric means 8 *vs.* 5; $P < 0.05$).

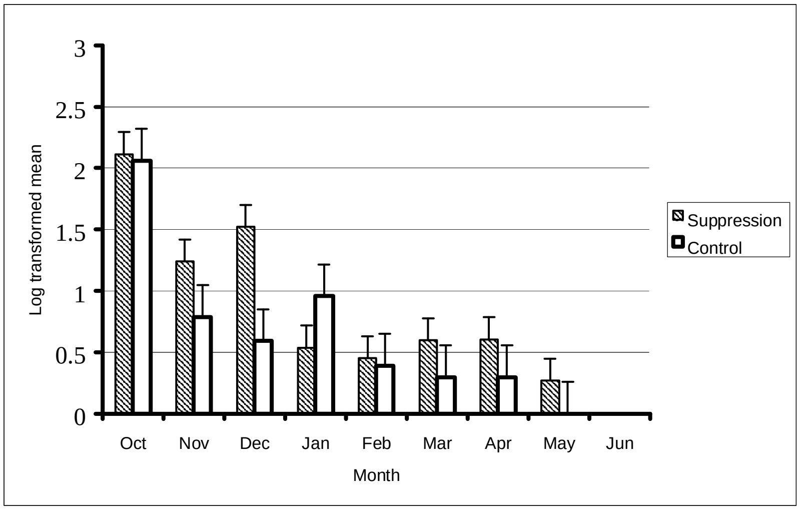

Figure 3. Mean $\log_{10}$ transformed *Lucilia* counts collected over a 48-hour period in the suppression and control areas of Langgewens. The vertical lines upon the hatched column represent standard errors.

At Elsenburg, *Lucilia* numbers were substantially lower than at the other localities (Fig. 4 compared with Figs 1,2 and 3).

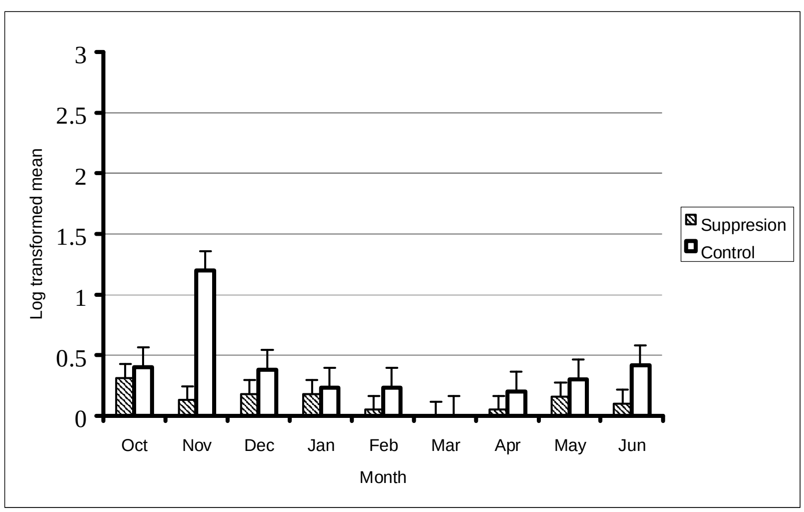

Figure 4. Mean log_{10} transformed *Lucilia* counts collected over a 48-hour period in the suppression and control areas of Elsenburg. The vertical lines upon the hatched column represent standard errors.

Given that the figures are on the log $_{10}$ scale, it is evident that the differences will be further accentuated on a normal scale. The designation or the trap interacted with month ($P = 0.02$), although blowfly counts were generally lower in the suppression area than in the control area. The only significant difference was, however, during November 1997 (respective log_{10}-transformed means and standard errors 1.20 ± 0.16 *vs.* 0.13 ± 0.12; respective geometric means 16 *vs.* 1; $P < 0.01$). It is probably also important to note that the counts for the respective months did not differ ($P < 0.05$) from zero in many cases.

Selectivity of the traps

The November 1997 trapping yielded the highest blowfly numbers at all control localities, except for the Langgewens control, where the highest yield was recorded during October 1997. In the absence of a significant ($P < 0.05$) locality x species interaction, log_{10}-transformed mean (± *SE*) fly counts across localities are presented to indicate the species distribution. Counts for *L. cuprina* (1.70 ± 0.16; geometric mean = 50 flies per trap) exceeded ($P < 0.01$) that of *L. sericata* (0.88 ± 0.16; geometric mean = eight flies per trap). Even fewer flies of the genus *Chrysomyia* were found in the traps (0.46 ± 0.16; geometric mean = three flies per trap). This mean fly count differed ($P < 0.01$) from that of *L. cuprina*, and also tended to differ ($P < 0.10$) from that of *L. sericata*.

Counts for flies of the genus *Lucilia* were pooled for the final analysis, and compared to counts for *Chrysomyia* spp. within localities (Table 1). It is evident that *Lucilia* spp. were more ($P < 0.05$) likely to be trapped than *Chrysomyia* spp., irrespective of the locality. The difference only approached significance at the Tygerhoek locality ($P < 0.10$), but a fairly large absolute difference nevertheless prevailed.

Table 1. Species distribution (expressed as proportions) of the blowflies recovered from monitor traps on the control areas during the month with the highest *Lucilia* yield (October 1997 for Langgewens, November 1997 for the other localities).

Locality[a]	*Lucilia* spp.			*Chrysomyia* spp.		
	Mean (SE)	10^b	Range	Mean (SE)	10^b	Range
Caledon	1.92(0.19)	83	4 – 471	0.41(0.19)	3	0 – 5
Tygerhoek	1.91(0.35)	82	6 – 630	1.05(0.35)	11	0 – 97
Langgewens	2.06(0.35)	155	34 – 429	0.39(0.35)	3	0 – 14
Elsenburg	1.20(0.35)	16	4 - 29	0.00(0.35)	1	0

Means for *Lucilia* and *Chrysomyia* counts differed ($P < 0.05$) within rows for Caledon, Langgewens and Elsenburg. A similar tendency ($P < 0.10$) was found at Tygerhoek.

[a] Based on the total yield of ten traps at Caledon and three at the other locations

[b] The geometric mean, depicted by the antilog of the mean

DISCUSSION

Monthly *Lucilia* yield in the suppression and control areas

Large-scale trapping appeared to be effective in controlling the *Lucilia* population at Caledon. A similar tendency was observed at Elsenburg, notwithstanding very low levels of activity. The *Lucilia* population at Tygerhoek and Langgewens did not decline relative to the population in the corresponding control areas. Trapping of *L. cuprina* over large areas was effective in reducing blowfly populations in Australia (Urech *et al.*, 1996; Urech *et al.*, 1998), comparable to the responses obtained at Caledon and Elsenburg. The lack of response to trapping at Tygerhoek and Langgewens is possibly due to the fact that a relatively small area was trapped. It was hypothetically impossible to control the influx of *Lucilia* from adjacent sheep-producing areas. Although *Lucilia* spp. were reported not to migrate over long distances, as indicated by DNA typing (Gleeson and Heath, 1997), the suppression area was probably too small for effective control at these localities. An explanation is required for the level of success at Elsenburg, where a relatively small area was trapped as well. Since vineyards surrounded this locality, it was probably too isolated from other sheep-producing areas to be affected by an influx of *Lucilia* from neighbouring areas. The low overall levels of *Lucilia* activity at Elsenburg could also be regarded as evidence of its isolation, since particularly *L. cuprina* has evolved to be largely dependent on the presence of live sheep for the completion of its life cycle (Howell *et al.*, 1978). It has been demonstrated that flies hatched from carcasses, for instance, made a very small contribution to the *L. cuprina* population (Cook *et al.*, 1996).

The procedure of using existing suppression traps for monitoring in the suppression area differed from the protocol used by Urech *et al*., 1996; Urech *et al*., 1998. It was subsequently brought to our attention that the chemicals used to manufacture the attractant adsorb to the surfaces of the container with continuous use (R. Urech, pers. comm.)Animal Research Institute, Department of Primary Industries, Queensland, Australia. This results in these traps becoming a larger source of the odour typical to the attractant. These traps thus probably had a stronger luring effect on the insects in the vicinity than traps in the control areas, which were exposed to the chemicals only once a month for 48 hours. The results of this investigation, and possibly the slightly higher overall *Lucilia* counts in the Langgewens suppression area in comparison with the control area, probably reflects this effect.

Selectivity of the traps

The synthetic attractant employed in the Lucitrap® system appeared to be highly effective for the trapping *Lucilia* spp., and particularly *L. cuprina*, at all the localities. Notable numbers of *L. sericata* were also trapped at all localities. The efficacy of the synthetic lure to attract this species has not been assessed (R. Urech, pers. comm.) This species has, however, been reported to be responsible for strikes on live sheep in South Africa, the United Kingdom and New Zealand (Smit and Du Plessis, 1927; Miller, 1939; MacLeod, 1943; Atkinson and Leathwick, 1995). The importance of *L. sericata* as a primary strike blowfly was, however, small relative to that of *L. cuprina* where both species were present (Atkinson and Leathwick, 1995). The species distribution of the natural blowfly population was not investigated at any of the localities. It is thus important to relate the yield from the traps to the natural blowfly population. Leipolt (1996) found that *L. sericata* accounted for 85 % of Calliphoridae trapped when using a liver-dung-Na_2S attractant in the central, summer rainfall parts of South Africa. *L. cuprina* constituted only a small percentage (11.5 %) of Calliphoridae trapped. A similar result was reported when using sheep offal-Na_2S bait in bin traps (Atkinson and Leathwick, 1995). Behaviour involving host location and oviposition appears to be similar for the two species (Ashworth and Wall, 1994).

CONCLUSIONS

Large-scale trapping appeared to be effective in reducing *Lucilia* populations when large areas were trapped (Urech *et al*., 1996; Urech *et al*., 1998). In the current study, it also seemed to be effective when applied to isolated sheep-breeding operations. The biology of the *Lucilia* spp. appears to make control by large-scale trapping a viable proposition (Ashworth and Wall, 1994). Large-scale trapping may be of value as part of an integrated blowfly management strategy in the sheep-producing areas of South Africa, as is envisaged in Australia (Urech *et al*., 1996; Urech *et al*., 1998). The results from the present study were inconclusive as far as the response of *Lucilia* populations to trapping was concerned, possibly owing to factors mentioned in the discussion. The effect of a reduction in blowfly numbers associated with suppression of the blowfly population using the Lucitrap® system on flystrike and the necessity of pesticide application has also not yet been studied. It is emphasised that industry will gain from a reduced reliance on chemicals, as the risk of contamination is difficult to predict (Plant *et al.*, 1999). It appears that the Lucitrap® system could be used to great effect for trapping *Lucilia* spp., which may be of value when monitoring blowfly populations for strategic decision-making is considered. The application of the present findings for practical sheep husbandry and animal health must therefore warrants further study.

ACKNOWLEDGEMENTS

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CHAPTER 3

THE APPLICATION OF TRAPPING, USING THE LUCITRAP® SYSTEM, IN AN INTEGRATED BLOWFLY MANAGEMENT PROGRAM IN SOUTH AFRICA

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ABSTRACT

The large-scale trapping of blowflies of the genus *Lucilia*, using an insecticide free trapping system (Lucitrap®), was evaluated for use in an integrated pest management program in the Western Cape. Traps were set at three localities in the two cropping-pasture areas of the Swartland and South Coast regions. These areas were referred to as suppression areas, on the assumption that trapping will affect the *Lucilia* populations therein. Control sites, where no suppression was practiced, were identified for each of these localities. The *Lucilia* population was monitored for 48 hours at each of the localities on a monthly basis. Five traps were used to monitor the blowfly populations within each of the suppression areas and the adjacent control areas. In the Swartland region, the overall yield of flies of the genus *Lucilia* in the suppression and the neighbouring control areas was similar over a 46 - month period from October 1998 to June 2002 (four *vs*. four flies per trap, respectively). In the South Coast localities, *Lucilia* numbers were generally reduced ($P < 0.01$) in the suppression areas compared to the control areas over the 46 - month trial period. Respective overall means in the Caledon area were 18 *vs*. eight flies per trap, *i.e*. a reduction of 56%. Corresponding means in the Riviersonderend area were 19 *vs*. ten flies per trap, *i.e*. a reduction of 47%. Designation of the monitoring trap, however, interacted with year and season in the Riviersonderend locality, possibly owing to very low catches during winter, when fly numbers trapped did not differ from zero, as well as a reduction in the relative yield of traps in the suppression area compared to control traps. Geometric means for blowfly numbers at all three localities were generally > 100 flies per trap for spring and early summer. It was concluded that large-scale trapping of blowflies may be of value in an integrated pest management system particularly in areas where high fly counts occur. Further work is being conducted.

Keywords: Flystrike, trapping, woolled sheep

INTRODUCTION

Blowflies have been seen as economically important ecto-parasites of sheep for nearly a century. The blowfly *Lucilia cuprina* is responsible for almost all primary strikes (De Wet *et al.,* 1986), while *Lucilia sericata* has also been reported to be responsible for strikes on live sheep in South Africa (Leipoldt and Van der Linde, 1997), the United Kingdom (Atkinson and Leathwick, 1995) and New Zealand (Miller, 1939). Blowfly control relies largely on insecticides (Howell *et al.*, 1978; Hughes and Levot, 1987), although certain strains of *L. cuprina* have demonstrated an ability to develop resistance to these chemicals (Hughes and

McKenzie, 1987; Wilson and Heath, 1994; Gleeson and Heath, 1997). There is growing concern about the accumulation of pesticide residues in the environment and in agricultural products. International trade agreements thus increasingly strive to minimize harmful chemical residues in products. Alternative measures therefore need to be assessed for the management of the blowfly problem in an integrated manner, resulting in a more sustainable approach.

According to French *et al*. (1992) the control of blowfly strike is based upon the reduction of the fly population and/or the susceptibility of the sheep. One component in an IPM program can be the use of blowfly traps to reduce the blowfly challenge. Gleeson and Heath (1997) reported in an investigation in New Zealand on the population biology of *L. cuprina* using a trap. The results from their survey provided evidence that *L. cuprina* is restricted to sheep farms and, within these, is predominantly found in the presence of sheep. Their results suggested that localized control measures such as large-scale trapping and genetic control techniques have potential for controlling *L. cuprina* numbers while reducing reliance on insecticide use.

The development of traps spans a period of many decades (Hutchinson, 1997). MacKerras *et al*. (1936) described a bait bin, based on liver and sodium sulfide that reduced blowfly strike by up to 50%. This general approach was still being followed in the 1980's (Anderson *et al*., 1990).

Traps are also used for the purpose of monitoring, ecological studies and in a few cases population control (Ward and Farrell, 2000). Carrion-baited traps have been used extensively to sample field populations (Vogt *et al*., 1985; Dymock and Forgie, 1995).

Numerous modifications of the "West-Australian" flytrap first described by Newman and Clark (1926) have been made over the years. In 1994 an Australian–developed, insecticide-free trapping system, the Lucitrap® (Miazma, Pty. Ltd. Mt. Crosby, Queensland, 4306, 1994) was released. This system makes use of a synthetic attractant developed by Urech *et al*. (1993) for *L. cuprina.* An adaptation has been made to this trap as well since 1994. Currently a three-bottle system is in use for the lure and not the two-bottle system. For the purpose of this study we continued using the two-bottle system. The trap is also currently under distribution by Bioglobal and will therefore be referred to as such in the following chapters.

The Lucitrap® may benefit the South African sheep industry. Ward and Farrell (2000) reported that the Lucitrap® system requires minimal ongoing labor input, unlike bait bins. The synthetic lures used in this system appear to be more attractive to *L. cuprina* (Urech *et al*., 1996) than the carrion and sodium sulfide baits used previously by Dymock and Forgie (1995). Urech *et al*. (1996) demonstrated the effectiveness of the Lucitrap® system in reducing blowfly populations in the field. This system was found to reduce blowfly populations at two Queensland localities (Urech *et al*., 1996). The study was extended to cover 21 trials in five Australian states over three summers (Urech *et al*., 1998). Suppression of the blowfly population, amounting on average to 77%, was achieved in 62% of these trials. No conclusion could be drawn in 24% of the trials, owing to very low fly counts during very dry conditions. Ward and Farrell (2001) reported a 46% reduction in strike rate in a trial conducted in southern Queensland by using this trap. This study evaluates the effect of this trapping system on population numbers for South African *Lucilia* spp.

MATERIAL AND METHODS

The large-scale trapping of blowflies, using the Lucitrap® was evaluated for use in an integrated pest management program. A synthetic attractant served as lure to entice blowflies into the trap and once the flies were inside the trap they found it difficult to escape and died of dehydration and starvation. One trap per 100 breeding ewes was set in sheep paddocks during early spring. With the flock structure in the South African industry, this corresponded to approximately one trap per 162 - 175 sheep. This ratio is above the one trap per 100 sheep prescribed by the manufacturer (Miazma, Pty. Ltd. Mt. Crosby, Queensland, 4306, 1994). Since usage of the Lucitrap® system mostly resulted in a reduction of the blowfly population (Urech *et al.*, 1996; Urech *et al.*, 1998), these areas will be referred to as suppression areas. In each of three localities a suppression area of > 50 km^2, as well as a neighbouring control area, were identified for monthly monitoring. These localities were situated in the pasture-cropping regions near to Caledon and Riviersonderend in the South Coast region and between Malmesbury and Moorreesburg in the Swartland region (Figure 1). The dominant farming enterprises at all three localities are grain cropping as well as sheep farming for wool and meat production. More details on the approximate locality positions, topography etc. were provided by Scholtz *et al*. (2000). In each locality, five traps were permanently placed in the suppression areas while five other traps were placed in nearby (< 5km) control areas. These traps were baited on a monthly basis from October 1998 to June 2002. The contents were quantitatively recovered after a 48-hour period, divided according to species and counted.

Routine management strategies, representative of those applied in the regions, were followed on the farms included in the study for the experimental period. These involved the spot treatment of strikes, as well as preventive treatment when an increase in blowfly numbers was expected. Non–insecticidal protective agents like Vetrazin® (Cyromazine, Novartis Animal Health) were sometimes used.

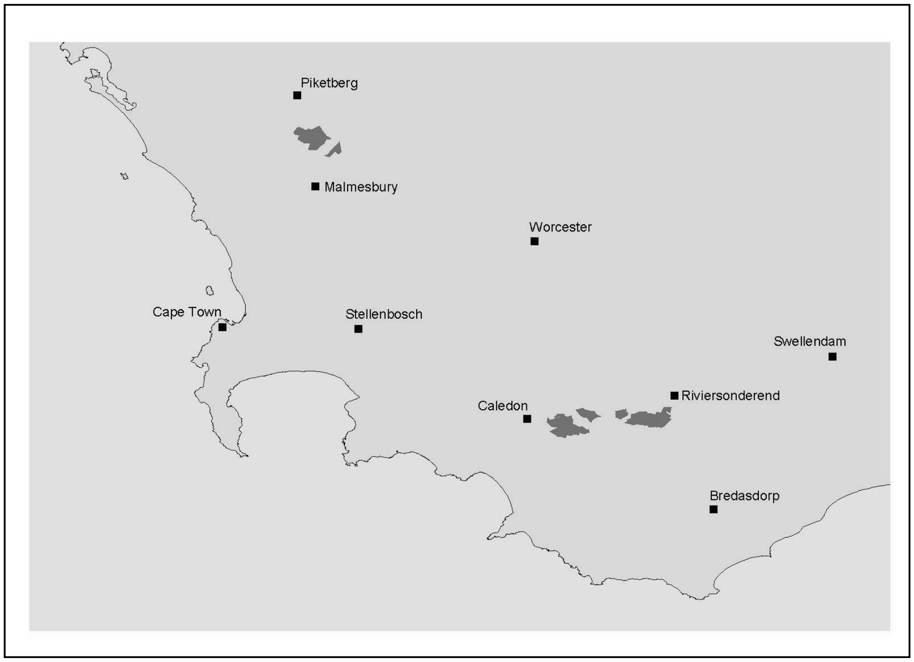


Figure 1. An area chart of the Western Cape region depicting the location of the three experimental sites (Malmesbury, Caledon and Riviersonderend). The suppression areas with their respective smaller control areas are in the brown shade.

Statistical analysis

The *Lucilia* spp (*L. cuprina* and *L. sericata)* were pooled for the analysis. Within locations, the data were subjected to a 2 X 46 factorial analysis (Snedecor and Cochran, 1967), the factors being the designation of the monitor trap (situated in a suppression or control area) and month (from October 1998 to June 2002). These results were found to be rather difficult to interpret, and it was decided to simplify the analyses by considering season (spring, summer, autumn and winter) rather than month. In these analyses, October represented spring, January summer, April autumn and July winter. The analysis was thus simplified to a 4 X 4 X 2 factorial (Snedecor and Cochran, 1967). The factors were year (1998/99 to 2001/02), season (spring, summer, autumn or winter) and designation of the monitor trap (suppression or control). Before analysis, fly counts were transformed to natural logarithms. Three were added to all fly counts prior to analysis, to account for zero counts. Data were presented as main effects or interactions, depending on the statistical significance. In cases where the designation of the trap interacted with year, significance at $P < 0.10$ was accepted, since this interaction formed the basis of the experimental outlay. All traps were identified with a unique number. Trap was included as an additional random factor in all analyses, to account for the covariation arising from the same trap being sampled repeatedly. Random trap effects were generally not significant, and were excluded from the results and discussion.

RESULTS

Where means on the natural logarithmic scale were presented in graphs, it was standardised to the same scale.

The blowfly species identified were *L. cuprina*, *L. sericata*, *Chrysomyia albiceps*, *C. chloropyga* and *C. marginalis*. Total monthly rainfall and average temperature were recorded for the respective localities. Monthly average temperature, total rainfall and geometric mean fly counts derived from natural logarithm transformed data are given in figures 2 to 4 for the Malmesbury, Caledon, and Riviersonderend localities. Average temperature followed a typical seasonal tendency at all localities, with maxima in the order of 23 - 26°C in summer and minima in the order of 11 - 13°C in winter.

Rainfall at the Malmesbury locality was mostly confined to the winter, although total monthly precipitations exceeding 20mm was also recorded during October – December 1998 and January – February 2002 (Figure 2). Rainfall at the other two localities were much more aseasonal and substantial falls, exceeding 50mm per month were recorded during the summers of 1998 and 2002 (Figures 3 and 4). The total monthly precipitation at the Riviersonderend locality also exceeded 50mm during January 1999 and March 2000. Geometric means for total *Lucilia* counts in the control area of the Malmesbury locality exceeded 100 flies per trap per 48 hours during spring in 1998 and 1999 (Figure 2). During subsequent years, these spring peaks were lower, and *Lucilia* numbers rarely exceeded 20 flies per 48 hours. At the two Southern Cape localities *Lucilia* counts remained above 20 flies per 48 hours for extended periods during the spring and summer of all years (Figures 3 and 4). Counts exceeding 100 *Lucilia* per trap per 48 hours were generally recorded for at least two months in the control area, during all the years except 2000/01.

Although the designation of the trap interacted with month in the overall, 2 x 46 factorial analyses conducted initially; overall means are provided, to give readers an indication of the levels of suppression achieved. At the Malmesbury locality overall means (± *SEs*) for *Lucilia* counts per trap over 48 hours amounted to 1.93 ± 0.29 in the control area and 1.92 ± 0.29 in the suppression area (*P* > 0.05). Back transformed geometrical means amounted to four flies per 48 hours in both instances. Overall means at the Caledon and Riviersonderend localities were lower (*P* < 0.01) in the suppression areas than in the control areas. Geometrical means in Caledon were respectively 18 and eight flies per 48 hours per month, indicating an average level of suppression of 56% (Means ± *SEs:* 3.05 ± 0.29 *vs*. 2.39 ± 0.29 respectively). Corresponding figures for Riviersonderend amounted to 19 and 10 flies respectively, with the average level of suppression at 47% (3.1 ± 0.21 *vs.* 2.59 ± 0.21 respectively).

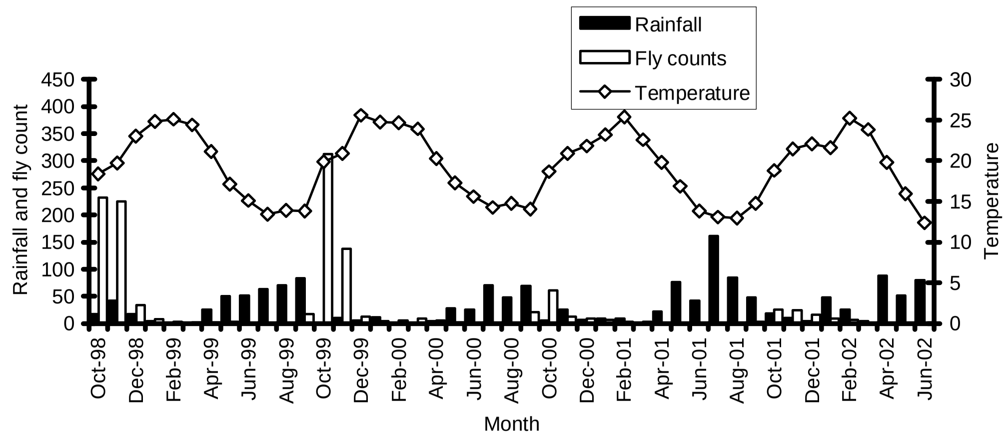


Figure 2.

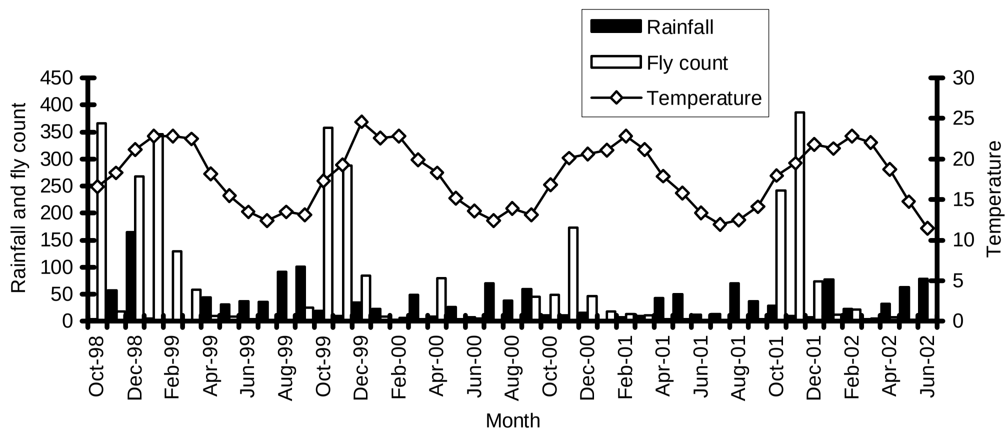


Figure 3.

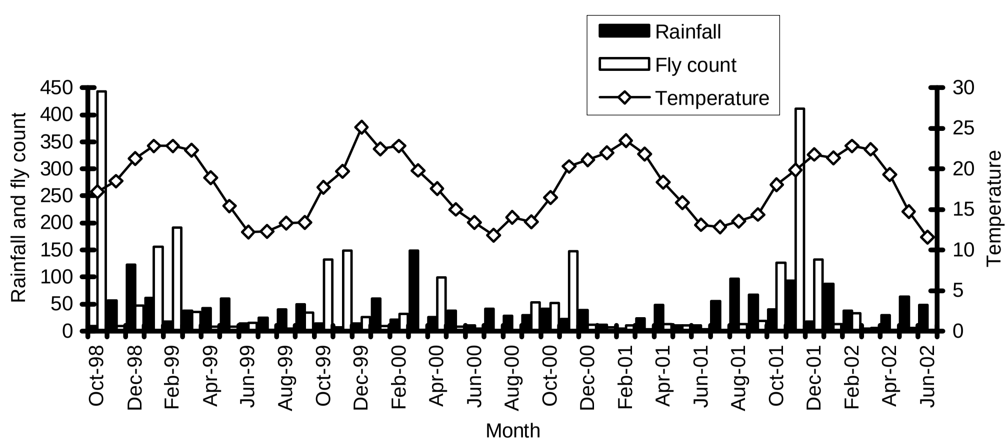


Figure 4.

Figures 2 – 4. Total monthly rainfall, average temperature and *Lucilia* counts (geometric means) averaged over five control traps for the Malmesbury (top), Caledon (middle) and Riviersonderend (bottom) areas.

Fly counts that were recorded on the Caledon locality over the period from October 1998 to July 2002 followed a typical annual trend (Figure 5).

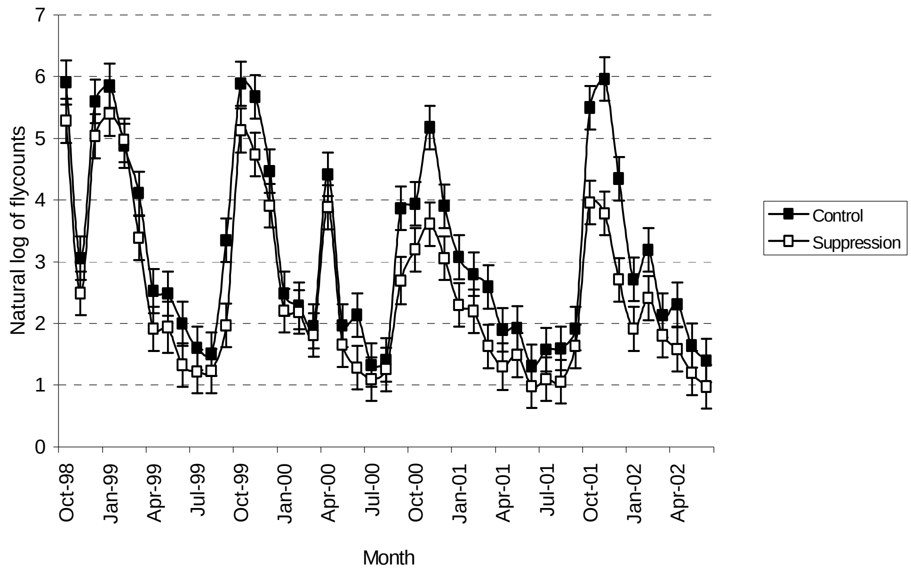


Figure 5. Monthly mean *Lucilia* counts averaged over five monitor traps in each of the suppression and control areas of the Caledon locality. Means were transformed to natural logarithms prior to analysis. Vertical lines about the respective means denote standard errors.

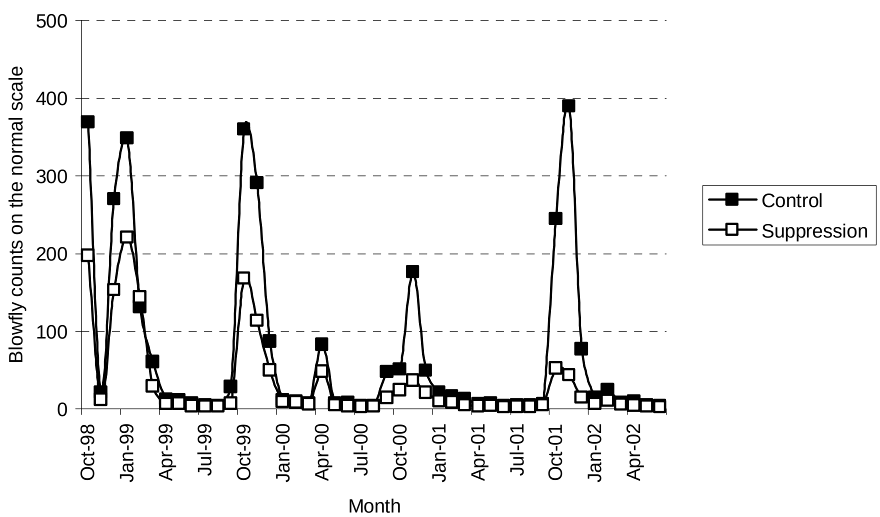


Figure 6. Monthly mean *Lucilia* counts averaged over five monitor traps in each of the suppression and control areas of the Caledon locality, on a normal scale. Means were derived from the analysis on transformed data presented in Figure 5.

Initially, no significant (*P* < 0.05) differences were found between monitor traps in the control and suppression areas. By the spring of 1999 (October and November 1999), fly counts in the control area traps were higher (*P* < 0.05) compared to suppression areas. In the following two years, these differences persisted for most of the spring/summer seasons (September 2000 to March 2001 and October 2001 to February 2002). During winter periods, fly counts in both the suppression and control areas dropped very low, and were generally not significantly (*P* < 0.05) different between suppression and control areas. During mid - winter (June and July 1999, 2000, 2001 as well as June and July 2002), fly counts generally did not differ (*P* < 0.05) from zero. Data for this locality is also provided on a natural scale in Figure 6. It is evident that fly counts in the suppression area amounted to only respectively 21 % and 11 % of that recorded in the control area during October and November of 2001.

Results from the 4 X 4 X 2 factorial design will be presented next. F-values and significance levels arising from these analyses are presented in Table 1, for analyses involving *Lucilia* counts within seasons. In the case of the Caledon and Malmesbury localities, the three-factor interaction between years, season and the designation of the trap was not significant. Designation of the trap was also not involved in interactions with the other main effects in the case of the Caledon locality (Table 1). The overall mean (± *SE*) for monitor traps in the suppression area was 2.15 ± 0.33 compared to 3.02 ± 0.33 in the control area (*P* < 0.05). Respective means were 20.5 and 8.6 on the normal scale. The designation of the trap interacted (*P* < 0.10) with year for the Malmesbury locality (Table 1).

Table 1. F-values and indications of significance for the 2 X 4 X 4 factorial analyses, involving the main effects of designation of the monitor trap (in a suppression or control area), season (spring, summer, autumn or winter) and year (1998/99, 1999/2000, 2000/01 and 2001/02). Residual mean squares are also provided.

Effect (degrees of freedom)	**Locality**		
	Malmesbury	**Caledon**	**Riviersonderend**
Designation of trap (D – 1)	1.88 **NS**	5.25*****	8.08******
Year (Y – 3)	4.58******	23.85******	32.32******

Season (S – 3)	187.79**	134.22**	120.79**
D X Y (3)	2.31#	0.93 **NS**	3.15*
D X S (3)	3.83*	2.47#	3.84*
Y X S (9)	6.44**	15.29**	13.38**
D X Y X S (9)	1.03 **NS**	0.45 **NS**	2.12*
Residual (125 – 128)	0.509	0.709	0.668

NS – Not significant ($P > 0.05$); **#** Significant ($P < 0.10$); ***** Significant ($P < 0.05$); ****** Significant ($P < 0.01$).

During 1998/99, the mean for the monitor traps in the suppression area was substantially lower ($P < 0.05$) than the corresponding mean for the control area (Figure 7). A similar tendency was detected for the 2000/01 year. No difference was, however, found during 1999/2000 and during 2001/02.

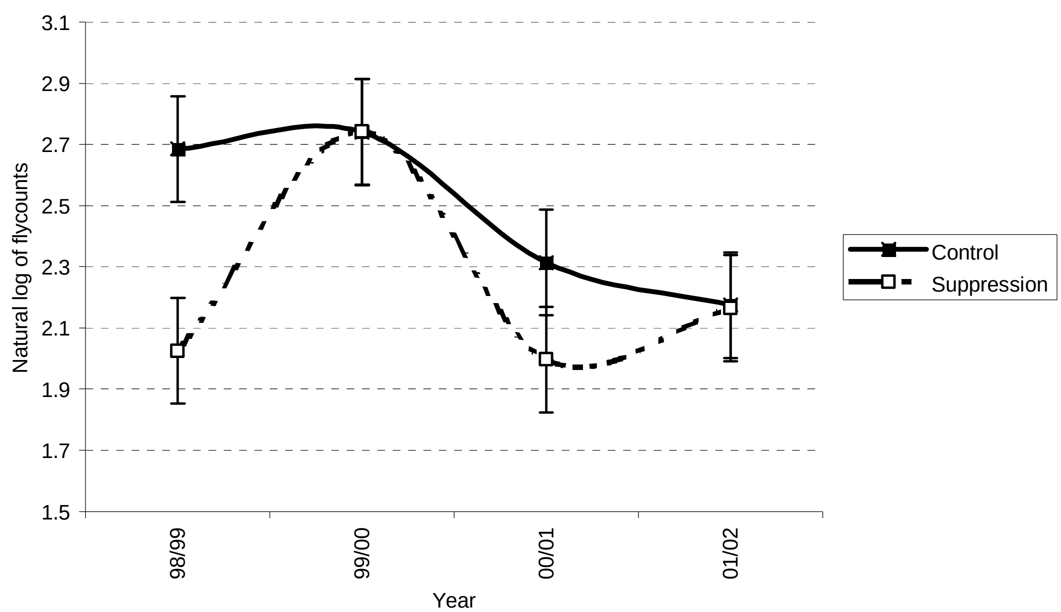
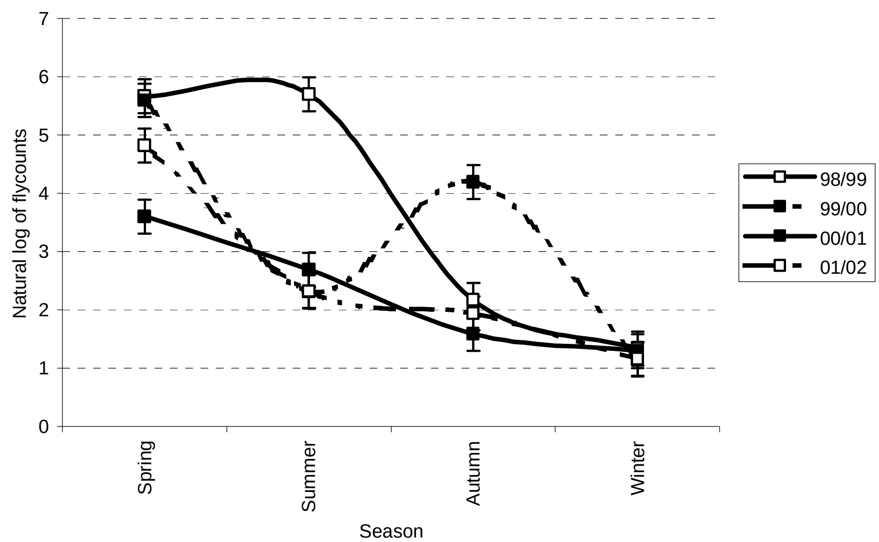


Figure 7. Means depicting the interaction between designation of the trap and year in the case of the Malmesbury locality. Vertical lines about the means represent standard errors.

Year interacted ($P < 0.01$) with season in both the Caledon and Malmesbury localities (Table 1). In Caledon, the interaction arose from high (compared to the other years) blowfly counts during the summer of the 1998/99 season and the autumn of the 1999/2000 season (Figure 8). Counts obtained during the



spring of 2000/01 also were substantially lower ($P < 0.05$) than in the other years.

Figure 8. Means depicting the interaction between season of sampling and year for the Caledon locality. Vertical lines about the means represent standard errors.

At the Malmesbury locality, blowfly counts generally declined curvi-linearly from spring to winter in most of the seasons (Figure 9), although this decline was slower during 2001/02. The trend obtained for 1999/2000 however, was different in shape. From the highest ($P < 0.05$) mean for all years during spring, fly counts declined markedly to summer, before increasing again to a level significantly ($P < 0.05$) higher than in other years during autumn (Figure 10). Counts obtained from the winter seasons were very low, and generally not different from zero at both localities (Figures 8, 9 and 10).

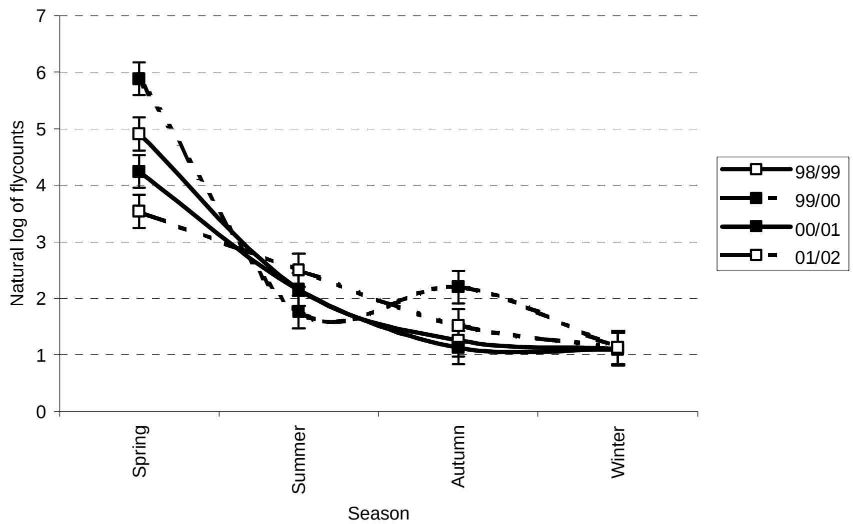


Figure 9. Means depicting the interaction between season of sampling and year for the Malmesbury locality. Vertical lines about the means represent standard errors.

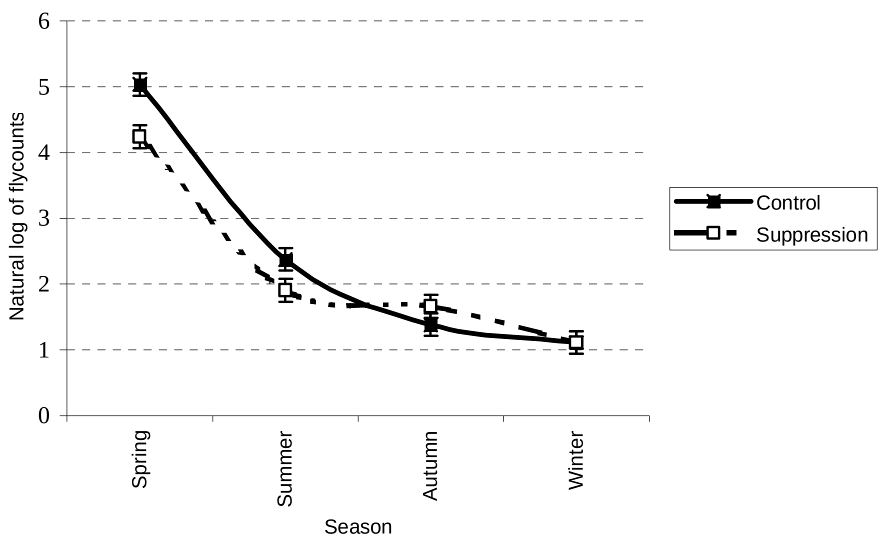


Figure 10. Means depicting the interaction between designation of trap with season of sampling for the Malmesbury locality. Vertical lines about the means represent standard errors.

The designation of the trap interacted ($P < 0.05$) with season at the Malmesbury locality (Figure 10 and Table 1). This interaction mainly resulted from suppression area means being generally lower than those of the control area during spring and summer, with a reversed trend during autumn.

The three-factor interaction between year, season and the designation of the trap was significant at the Riviersonderend locality (Table 1 and Figure 11).

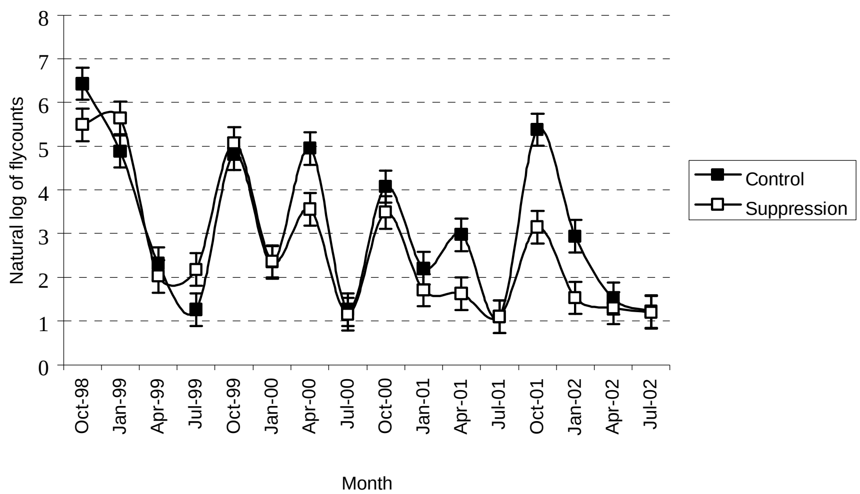


Figure 11. Means depicting the three-factor interaction between designation of the trap, season of sampling and year for the Riviersonderend locality. Vertical lines about the means represent standard errors.

During 1998/99, no clear pattern emerged for means derived for the monitor traps in the control or suppression areas, with significant differences occurring in both directions. During the autumn of 2000, the suppression area means fell below ($P < 0.05$) that of the control area (Fig.11). A similar result was obtained for the autumn of 2001, for the suppression trap means obtained during the spring of 2001 and the summer of 2002. Transformed to the natural scale, the yield of suppression area monitor traps constituted only between 11 % and 26 % of the corresponding means in the control area during this period.

DISCUSSION

To simplify interpretation, results are discussed under a number of headings.

Climate in relation to long-term trends

Total long-term rainfall figures for the respective localities were 395.3 mm at Malmesbury, 494.4mm at Caledon and 429.1 mm at Riviersonderend. The long-term rainfall distribution at the localities differed markedly. In total, 78% of the total precipitation at Malmesbury was recorded in the period from April to September. Corresponding figures were 69% at Caledon and 60% at Riviersonderend. The greater likelihood of rain during summer at the Caledon and Riviersonderend localities in comparison to the Malmesbury locality is evident from Figures 2 to 4. It is also expected that the rainfall pattern of the Caledon and Riviersonderend localities would be very similar, for these localities are in very close proximity (Figure 1).

Differences between years in seasonal trends

In general *Lucilia* numbers were high in spring and low in winter (Figure 8 and 9). These results are in accordance with the findings of Howell *et al*., (1978) reporting that the first wave of blowflies generally coincides with the first rains in spring, when adult flies emerge from the thousands of pupae in the soil in the summer rainfall area of South Africa. The finding in this study that fly numbers generally decrease during the warm summer months, until the autumn, when a second wave may be produced is also in accordance with the findings of Howell *et al*. (1978). Dymock *et al*. (1991) reported that *Lucilia* spp. were trapped during the months from November to May in New Zealand, with very few flies present during the winter months. Results from the present study support these findings (see Figure 5).

In the case of the Caledon locality the significant ($P < 0.05$) interaction between year and season mostly stemmed from a very high *Lucilia* yield during the summer of 1998/1999 and during the autumn of 1999/2000 (Figure 8). The same trend was evident from the Riviersonderend locality (Figure 11). The high *Lucilia* yield during the summer of 1998/1999 at these localities was probably related to substantial falls during November and December 1998 (222mm at Caledon and 181mm for Riviersonderend). A total precipitation of 48mm was correspondingly recorded for March 2000 at the Caledon locality. The comparable rainfall figure at Riviersonderend during this month was 149mm. The greater likelihood of rain during summer for the Caledon and Riviersonderend localities possibly explains the higher blowfly counts for these areas compared to Malmesbury (Figures 2 - 4).

In the case of Malmesbury, a correspondingly high *Lucilia* count was found during the autumn of 1999/2000 compared to the other years (Figure 9). This interaction was significant in statistical terms, but could not be attributed to known climatic data in this specific year. Even though the mean *Lucilia* numbers were higher during the autumn of 1999/2000 compared to the other years, it was still extremely low (a geometric means of 9 flies / trap) and thus of little practical significance.

The effect of trapping on blowfly numbers

When results from the three localities were considered, it was impossible to derive at a single robust conclusion. It was evident that large-scale trapping resulted in marked reductions ($P < 0.05$) in *Lucilia* counts at the Caledon and

Riviersonderend localities (Figures 5, 6 and 11). These reductions were particularly evident during spring, autumn and summer towards the end of the experiment.

When results for the Malmesbury locality was considered, no evidence of a reduction in the *Lucilia* population was observed at the end of the experimental period (Figure 7). At the commencement of trapping, however, substantially fewer flies were trapped in the suppression area compared to the control area. No apparent reason can be given for the difference in response to trapping between Malmesbury and the other localities. It can only be speculated that the lack of response at the Malmesbury locality is due to relative high blowfly numbers initially observed in the control area (in the spring of 1998/99 and 1999/2000 – see Figure 2). The substantial lower fly counts at the Malmesbury locality compared to Caledon and Riviersonderend is also evident from Figure 7, as compared to Figures 5, 8 and 11. The interaction of the designation of trap with season (Figure 10) may also be involved. Overall, mean *Lucilia* counts during the spring and summer were lower ($P < 0.05$) in the suppression area than in the control area, but this trend was reversed during autumn. It can furthermore be speculated that the lack of response in the Swartland area compared to the South Coast localities are due to climatic differences. The Swartland area is a typical winter rainfall region, while the South Coast is known for a higher probability of receiving rain throughout the summer period. This can clearly be seen in Figures 2 – 4. It can also be argued that the low blowfly numbers are due to the seasonal occurrence of blowflies for this locality, as determined by the lack of summer rain in most seasons. Urech *et al*. (1998) correspondingly reported poor responses to large-scale trapping that resulted from very low fly counts during very dry conditions in trials done by them.

The effect of blowfly trapping on the *Lucilia* populations in the control and suppression areas of the South Coast over a prolonged period is evident in the results (Figures 5, 6 and 11). At these localities trapping was effective in reducing *Lucilia* populations when large areas were trapped. The full magnitude of suppression on the *Lucilia* population is probably more evident when viewed on the normal scale for the Caledon locality (Figure 6). Similar results were previously reported on by Urech *et al.*(1996); Urech *et al.*(1998) and Scholtz *et al*. (2000).

CONCLUSION

The biology of the *Lucilia* spp. appears to make control by large-scale trapping a viable proposition (Ashworth and Wall, 1994). We thus conclude that large-scale trapping may be of value as part of an integrated blowfly management strategy in the sheep-producing areas of South Africa, as is envisaged in Australia (Urech *et al.* 1996; Urech *et al*.1998). The effect of a reduction in blowfly numbers associated with suppression of the blowfly population using the Lucitrap® system on flystrike and the necessity of pesticide application has not yet been studied in South Africa. There are indications that trapping may be effective in minimizing flystrike and pesticide application in Australia (Ward and Farrel, 2000).

It appears that the Lucitrap® system was effective in reducing the *Lucilia* spp populations in areas with a traditional high blowfly population, such as at Caledon and Riviersonderend. Unfortunately this result could not be extended with robustness to the Malmesbury locality, where lower overall *Lucilia* counts were found.

Apart from playing a role in an integrated pest management program, the system may also be of value when the monitoring of blowfly populations for strategic decision-making is required. The application of the present findings to practical sheep husbandry and animal health therefore warrants further study.

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CHAPTER 4

BLOWFLY NUMBERS IN RELATION TO CLIMATE IN THE SOUTHERN CAPE

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ABSTRACT

Blowfly strike in sheep has so far mostly been combated with chemicals. Resistance of blowfly strains to pesticides, as well as trade agreements to regulating the use of agro-chemicals, requires that other avenues need to be explored. The seasonal abundance and species distribution of blowflies belonging to the genera *Lucilia* and *Chrysomyia* were evaluated over a two-year period (1999 and 2000) at Tygerhoek in the Southern Cape. Flies were trapped using the Lucitrap® system. Fly counts were related to climate data to see if an accurate prediction of blowfly occurrence was possible for strategic decision-making. The vast majority (91.8%) of 73931 flies trapped over the two-year period belonged to the genus *Lucilia*. The most important primary strike blowfly (*Lucilia cuprina*) contributed 99.1% to *Lucilia* numbers. Most (88%) of 6042 flies belonging to the genus *Chrysomyia* were the species *C. albiceps*. Seasonal blowfly abundance occurred during the period from spring to mid summer of each year. There was evidence of secondary peaks during autumn. Relationships between climate and fly counts were relatively poor irrespective of the statistical methods used, and of limited predictive ability.

INTRODUCTION

Primary strikes of live sheep are predominantly related to a small number of metallic blowflies. The blowfly *Lucilia cuprina* is responsible for almost all primary strikes recorded in South African sheep flocks (Howell *et al*., 1978; De Wet *et al*., 1986). The species *Lucilia sericata* has also been reported to be occasionally responsible for strikes on live sheep in South Africa (Smit and Du Plessis, 1927). De Wet *et al.* (1986) reported *Chrysomyia chloropyga* to be responsible for a small percentage (about 10%) of primary strikes.

The control of blowflies in sheep still largely relies on the use of insecticides (Howell *et al.*, 1978; Hughes and Levot, 1987). The insects have shown the ability to develop resistance to commonly used insecticides (Fiedler and Du Toit, 1956; Hughes and McKenzie, 1987; Gleeson *et al.*, 1994; Wilson and Heath, 1994; Levot and Barchia, 1995; Wilson *et al*., 1996). Other control measures in use include the Mule's operation (Bull, 1931; De Wet *et al*., 1986), crutching, tail docking and better hygiene (French *et al*., 1992). These practices on their own are usually not sufficient for complete blowfly control.

A second argument against the use of pesticides lies in occupational health and safety. This concern arose in the meat trade during the mid 1980's, leading to the realisation that harvested wool also contained pesticide residues. This resulted in international environmental concern and strict legislation by the European Union (EU) on the minimisation of chemical residues in textiles.

Sustainable ectoparasitic control/eradication is thus an important aim for the sheep industry. Alternative means of fly control is urgently needed for integration with existing control procedures (Cottam *et al*., 1998). The most efficient method to achieve this aim is through integrated pest management (IPM) programs (Evans and Karlsson, 2000). The recent move towards pesticide residue minimization favours an IPM approach.

Heath (1994) recommended that farmer's install an "early warning" system using simple flytraps to monitor fly numbers and detect the emergence of blowflies. More efficient control may be effected by the adoption of strategic, early season control, as suggested by theoretical analysis (Wall *et al.*, 1993b) and demonstrated in the field for *L. cuprina* in Australia (McKenzie and Anderson, 1990). In a study done by Monzu (Bulletin 4101) on the relationship between fly numbers and strike, it was found that the presence of any *L. cuprina* flies in traps is ample warning that there are sufficient flies to cause a serious strike problem if all other conditions for strike are ideal.

In the summer rainfall area of South Africa the appearance of the first wave of blowflies generally coincides with the first rains in spring, when adult flies emerge in their thousands (Howell *et al*., 1978). During the warm summer months the fly numbers generally decrease until the autumn, when a second wave may be produced (Howell *et al*., 1978). For *L. cuprina* to become active, the maximum daily temperature for periods following the start of rain must be 17°C or greater, and the lower average wind speed range, less than 30km/hr (Monzu and Mangano, Bulletin 4101).

The infestation of sheep by the larvae of the blowfly *L. sericata* is a highly seasonal problem in Britain, affecting flocks between May and October (French *et al*., 1995). The first strikes are seen in spring after the overwintering larvae have pupated and emerged as adult flies (Davies, 1934; MacLeod, 1943; Wall *et al*., 1992). Wall *et al*., (1992; 1993a) reported that in England and Wales *L. sericata* populations pass through three or four generations before the offspring of the final generation enter diapause (Cragg and Cole, 1952). The precise timing of these events is highly dependent on ambient temperature (French *et al*., 1995). Seasonal strike incidence is related to both the abundance of the blowfly *L. cuprina* and a range of climatic and other environmental factors affecting sheep susceptibility (Wardhaugh and Morton, 1990). Body strike by *L. cuprina* is the most common form of flystrike in Australia and the incidence thereof is dependant on weather (Hayman, 1953, 1955; Wardhaugh and Morton, 1990), related to fleece rot (Belschner, 1937) and dermatophilosis (Gherardi *et al*., 1981; Gherardi *et al*., 1985). The affects of temperature, rainfall and other weather conditions on fly populations have been studied mainly in Australia and United Kingdom (Vogt *et al*., 1983; Wardhaugh and Morton, 1990; Wall *et al*., 1993a). So far, there has been a lack of local studies to complement those carried out elsewhere.

The purpose of this trial was to study the seasonal distribution of *Lucilia* spp. in relation to short-term weekly climate in the Southern Cape. Blowfly numbers derived from the Lucitrap® system (Urech *et al*., 1996) was used as an indicator of fly abundance.

MATERIAL AND METHODS

The experiment was conducted on the Tygerhoek Experimental Farm (± 800 ha) near Riviersonderend in the Southern Cape over a two-year period (1999 and 2000). The geographical position of the site was described by Scholtz *et al*. (2000). The Lucitrap® (Bioglobal Pty. Ltd., Level 1, 417 Collins St., Melbourne, Victoria 3000) (Urech *et al*., 1993; Urech *et al*., 1996; Urech *et al*., 1998) system was used to catch the flies. The trap was set up at a weather station, and constantly baited with Lucilure® over the experimental period. A contact insecticide was sprayed into the trap, the contents recovered quantitatively and preserved in 70% alcohol on a weekly basis. The blowflies were separated according to species (Howell *et al*., 1978). Metallic blowflies belonging to the genera *Lucilia* (*L. cuprina* and *L. sericata*) and *Chrysomyia* (*C. albiceps, C. chloropyga and C. marginalis*) were identified and counted separately. When very high weekly insect yields made counting impractical representative samples were taken from the weekly yield. From these samples, 200 insects were selected randomly, separated according to species and counted. This sample was subsequently dried at 60°C in an oven, until a constant weight was obtained. This weight was recorded, and the rest of that sample was treated in the same way. The numbers of the different insect species were estimated by applying the ratios derived from the sample. The weather data (minimum, maximum and average temperatures, rainfall, evaporation, sunshine, wind speed, maximum and minimum relative humidity) were recorded with a data logger during the entire period and averaged (totalled in the case of rainfall) to derive weekly means.

Statistical

Standard linear regression techniques were used to relate climatic data to total *Lucilia* and *Chrysomyia* counts (Snedecor and Cochran, 1967). Multiple linear regression and stepwise multiple linear regression techniques were subsequently used to relate combinations of climatic data to blowfly counts. Since multi-colliniarity often poses a problem when climatic data are considered, the PRINCOMP procedure of SAS (Anonymous, 1990) was used to obtain principal components based on the climate variables. Blowfly counts were subsequently regressed on these principal components, using the REG procedure of SAS (Anonymous, 1990).

RESULTS

The vast majority (91.8%) of 73931 blowflies trapped over the two-year period belonged to the genus *Lucilia*. The most important primary strike blowfly (*L. cuprina*) contributed 99.1% of the total *Lucilia* numbers, the remainder being made up by *L. sericata*. Correspondingly, most (88.3%) of 6042 blowflies belonging to the genus *Chrysomyia* that were trapped belonged to the species *C. albiceps*. Seasonal blowfly abundance followed a typical trend, with peaks where the weekly *Lucilia* yield would generally exceed 2000 flies during the period from spring to mid summer of each year (Figure 1). There was evidence of secondary peaks during autumn.

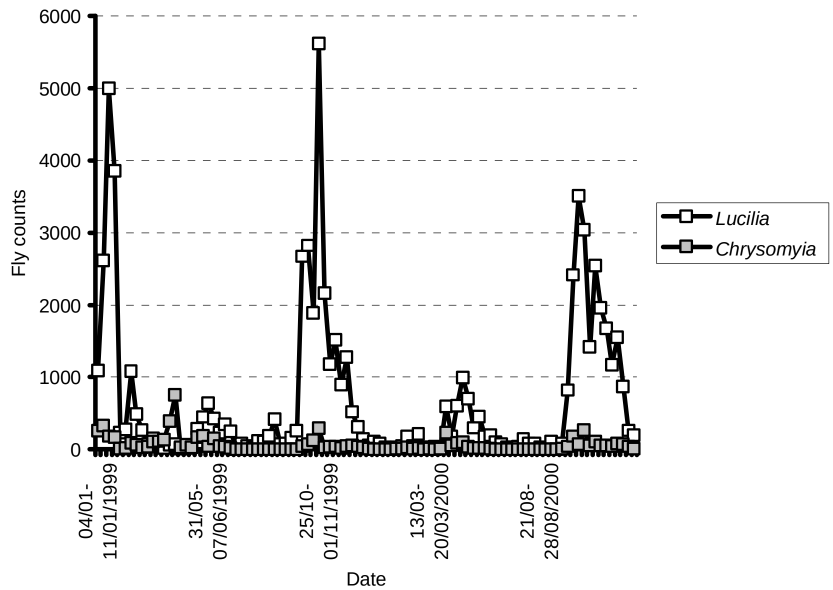

Figure 1. Weekly fly counts during the experimental period. Total numbers for the genera *Lucilia* and *Chrysomyia* are given.

Weekly *Lucilia* counts were related to some of the climate variables (Table 1), but the derived linear regressions failed to account for more than 19 % of the variation in fly counts. *Lucilia* counts were positively related to average temperature, total radiation, average windspeed and total evaporation. Relationships of weekly climate data with *Lucilia* yields were generally poor, R^2-values ranging from 0.04 for minimum temperature to 0.19 for total radiation. The relationship with relative humidity was negative, and a similar tendency (P = 0.07) was found for total rainfall. The independent variable most closely associated with *Lucilia* counts was total radiation. A scatter-plot depicting this relationship is provided in Figure 2. No significant relationships of climatic data with *Chrysomyia* counts were found (Table 1).

Models derived from multiple linear regression and stepwise regression procedures were significant ($P < 0.05$), but failed to account for more than 20% of the variation in *Lucilia* counts. The modeling of seasonal blowfly abundance, using climate data thus seems to be more complex than allowed for when using linear regression techniques.

Of the climate data available for analysis, it was decided to exclude maximum and minimum weekly temperatures at this stage. The correlations of maximum and minimum temperature with average temperature exceeded 0.95, and it was reasoned that they were essentially the same variables.

Table 1. Linear regressions relating climatic data to total counts of *Lucilia* and *Crysomyia*. Regression coefficients and intercepts are accompanied by standard errors for statistical evaluation.

Climatic variable and blowfly genus	**Intercept** ***A ± SE***	**Regression** ***b ± SE***	***R***	R^2
Average temperature (øC)				
Lucilia	490 ± 444	70.2 ± 25.5**	0.27	0.07
Chrysomyia	19.3 ± 44.3	2.51 ± 2.55	0.10	0.01
Total radiation (MJ/mý)				
Lucilia	-444 ± 260	10.2 ± 2.2**	0.44	0.19
Chrysomyia	43.0 ± 27.8	0.18 ± 0.23	0.08	0.01
Average windspeed (m/s)				
Lucilia	-385 ± 511	49.0 ± 22.7*	0.22	0.05
Chrysomyia	56.4 ± 50.5	0.24 ± 2.25	0.01	0.00
Total rainfall (mm)				
Lucilia	858 ± 143**	-17.3 ± 9.6 (0.07)	0.18	0.03
Chrysomyia	56.2 ± 14.0**	0.58 ± 0.94	0.06	0.00
Total evaporation (mm)				
Lucilia	-116 ± 215	27.5 ± 6.4**	0.40	0.16
Chrysomyia	45.9* ± 22.5	0.53 ± 0.68	0.08	0.01
Average relative humidity (%)				
Lucilia	3792 ± 1135**	-39.5 ± 14.4	0.27	0.07
Chrysomyia	134 ± 114	-0.93 ± 1.44	0.07	0.00

** - $P < 0.01$
* - $P < 0.05$

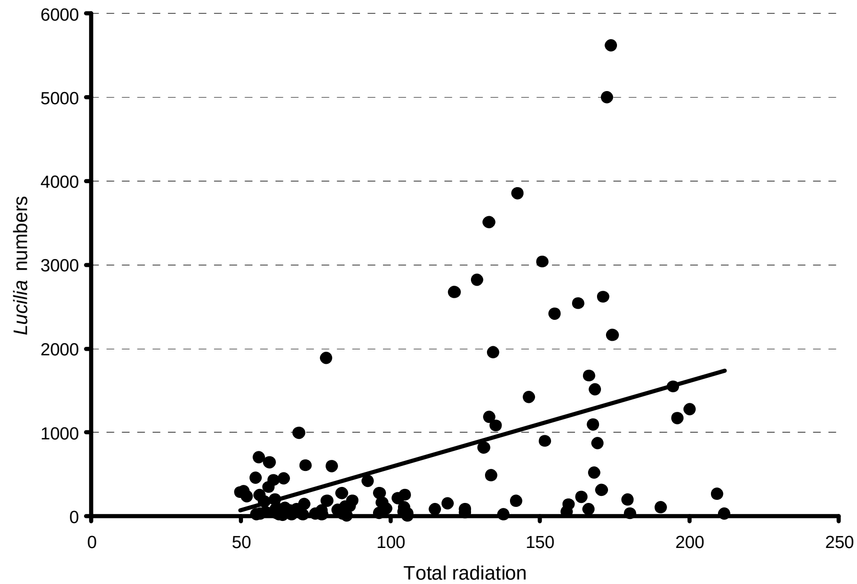

Figure 2. Scatter-plot depicting the relationship of weekly *Lucilia* counts with weekly total radiation values. The appropriate regression equation is given in Table 1.

Eigenvectors for the six principal components derived from the climatic data are given in Table 2. Eigenvalues derived from the data suggested that the relative proportions of the climate accounted for by the principal components were 0.65, 0.18, 0.08, 0.06 0.04 and 0.01. When *Lucilia* yield was regressed on these principal components, significant regression was found for principal component 1 and principal component 5. A tendency (*P* = 0.11) towards significance was also found for principal component 2. Only these principal components will thus be described further.

Table 2. Eigenvectors for the respective principal components (*PC*).

Climate variable	***PC1***	***PC2***	***PC3***	***PC4***	***PC5***	***PC6***
Average temperature (øC)	0.414	-0.001	0.664	0.553	-0.276	-0.077
Total radiation (MJ/mý)	0.480	-0.082	0.063	-0.228	0.584	-0.605
Average windspeed (m/s)	0.385	0.309	-0.696	0.517	-0.048	-0.049
Total rainfall (mm)	-0.071	0.944	0.244	-0.167	0.132	0.032
Total evaporation (mm)	0.496	-0.075	0.047	-0.156	0.328	0.784
Average relative humidity (%)	-0.446	-0.055	0.097	0.569	0.675	0.102

Eigenvectors for average temperature, total radiation, average wind speed and total evaporation were high and positive in principal component 1 (Table 2). Average relative humidity, on the other hand, had a negative eigenvector. This principal component thus appears to reflect hot, dry and windy conditions, with a high level of evaporation and low relative humidity. These conditions are typical of the summer climate at the experimental site. The second principal component has positive eigenvectors for average wind speed and total rainfall. This principal component thus seems to reflect rainy and windy conditions. In the case of the fifth principal component, eigenvectors for radiation, total evaporation, and particularly average relative humidity were positive and high. This principal component thus seems to reflect sunny and humid conditions.

The derived regression equation was as follows (principal component – PC; ± *SE*):

Lucilia count = 693 ± 100 + 207(± 51) PC1 – 160(± 98) PC2 + 485(± 217) PC5 (R^2 = 0.20)

Principal component 1 and 5 were positively related to the data, suggesting that blowfly numbers would increase under such conditions. Principal component 2 was negatively related to the data suggesting that windy, rainy weather tended (P = 0.11) to suppress blowfly numbers. The equation, however, still accounted for only 20 % of the variation in *Lucilia* numbers. A similar exercise for *Chrysomyia* numbers yielded no significant regressions, and is therefore omitted

DISCUSSION

Although the composition of the natural blowfly populations can only be speculated, it was evident that the majority of flies caught by the Lucitrap® system belonged to the genus *Lucilia* (Scholtz *et al.*, 2000). In the absence of data on the blowfly population occurring naturally, these trends cannot be regarded as a true reflection of the relative abundance of the respective species. It should be noted that the Lucitrap® system was developed specifically for the trapping of *Lucilia* spp.

Lucilia cuprina is recorded as the primary strike blowfly of South Africa (Howell *et al*., 1978; De Wet *et al*., 1986). Seasonal blowfly abundance followed a typical trend, with peaks where the weekly *Lucilia* yield would generally exceed 2000 flies during the period from spring to mid summer of each year. This trend accorded with corresponding trends reported by (Howell *et al*., 1978). There was evidence of secondary peaks during autumn. In New Zealand, *L. cuprina* is present throughout the summer. Numbers build up throughout January and February, while the species remains active until May (Dymock *et al*., 1991). It does not seem to have the distinct bimodal pattern of activity as was described in Australia, where numbers peak in September/October and again in March and April (Norris, 1991).

Additional evidence that blowfly numbers are expected to increase during summer stems from PC1. It correspondingly seemed as if blowfly numbers are expected to decrease when rainy, windy weather is experienced. These results are in accordance with figure 1 and the general perception in the literature (Wardhaugh and Morton, 1990; Monzu and Mangano, Bulletin 4101). Furthermore, blowfly numbers seem to increase during sunny, humid periods. This finding is consistent with that of (Hayman, 1953; 1955; Wardhaugh and Morton, 1990; Monzu and Mangano, Bulletin 4101) that humidity and prolonged moisture in the fleeces of sheep are conducive to increased blowfly activity and strikes resulting from favourable conditions.

Finally it has to be conceded that prediction equations derived from this study were too poor for accurate predictions. Factors possibly contributing to this finding include the fact that climate data was recorded at weekly intervals. This climate data may not predict fly numbers accurately because of a possible lay-phase between the occurrence of a climatic phenomenon and the reaction of the blowfly population to it. Cottam *et al*. (1998) indicated that climatic parameters two to four weeks prior to the specific fly count were more closely related to fly counts than short-term climate data, since the minimum generation time for the fly species considered is 16 – 35 days (Waller, 1984). Since the modelling of insect populations is also widely propagated (Wall *et al*., 1993a; McLeod, 2001; Sutherst *et al*., 2001), this aspect needs further inputs to arrive at a workable scenario, leading to more accurate predictions.

CONCLUSION

It is concluded that the population dynamics of blowflies are too complex to model with the relative basic statistic procedures utilized. Predictions failed to account for more than 20% of the variation in the observed fly counts. Additional analyses involving principal components derived from the climatic data, failed to provide additional accuracy. Since the procedures applied failed to predict blowfly occurrence with a reasonable degree of accuracy, further work is envisaged, as outlined in the discussion section.

The modelling of insect populations seems to hold promise for more accurate predictions of seasonal blowfly counts, and needs to be considered in future research.

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CHAPTER 5

GENERAL DISCUSSION

Insecticides have served the wool industry well and their cost effectiveness has never been questioned. This efficiency led to some producer's excessive reliance on insecticide treatments. The widespread use of chemicals resulted in the development of resistance to at least three insecticide classes in the sheep blowfly *Lucilia cuprina*. Organophosphate resistance in the sheep blowfly is almost universal (Levot, 2001). The worldwide growing concern with regard to the influence of chemicals on the environment and potential health risks to humans also resulted in strict international trade agreements like the Integrated Pollution Prevention and Control (IPPC) Directive (1996) imposed by the European Union (EU). A cause of concern for the South African Wool Industry is the absence of a policy on the control of potentially harmful chemicals in the wool clip. This may result in South African wool producers finding themselves out in the cold, being unable to produce wool with chemical residue levels within or below the allowed levels.

International trade agreements favour an Integrated Pest Management approach for the control of the sheep blowfly. The control of sheep ectoparasites is an integration of sheep husbandry, farm management and insecticide use (Levot, 2001). French *et al*. (1992) reported that the control of blowfly strike is based upon the reduction of the fly population and/or the reduction of susceptibility of the sheep. One component in an IPM program that can be considered is blowfly traps to reduce the blowfly challenge. Localized control measures such as large-scale trapping and genetic control techniques have potential for controlling *L. cuprina* numbers while reducing reliance on insecticide use (Gleeson and Heath, 1997).

From this study it was evident that the long-term usage of Lucitrap® may reduce the blowfly population. This would in all probability lead to a reduced challenge, as was reported by Ward and Farrell (2001). In a study by Horton *et al*. (2001a) on the other hand, no substantial reduction in flystrike or insecticide treatments were found. Although most pesticide applications for blowfly control do not necessarily result in unacceptable pesticide residues on wool, a substantial proportion of woolgrowers apply pesticides (for a variety of reasons) too close to shearing, resulting in unacceptable residue levels (Ward and Armstrong, 1998). The use of the Lucitrap® system will be most effective in reducing pesticide residue levels if late season applications can be avoided (Ward and Farrell, 2001).

Evidence suggested that usage of Lucitraps® for several years at a high rate (at least 1 trap per 200 sheep) reduced the number of flies in the area and decreased flystrike to an extent that allows a reduction in the frequency of preventative flock treatment (Horton, 1999). Overall reductions of respectively 56% and 47% in blowfly populations in the suppression areas were recorded for the Caledon and Riviersonderend localities in the present study (Chapter 3). These reductions are probably attributable to the use of the Lucitraps at a high rate (1 per 100 breeding ewes) for a five-year period. This study did not examine strike incidence or insecticide treatments in the suppression and control areas. No conclusions can therefore be made under South African conditions, but it is intended to investigate this in the very near future. Horton *et al.* (2001a) reported that some property owners in Tasmania believed that the Lucitraps® had been of some assistance in reducing flystrike. The owners also believed that it kept fly strike at manageable levels when the weather conditions were suitable for the development of flystrike. The previous authors concluded that the traps reduced flystrike with no more than 50% and that this on its own was insufficient to reduce chemical usage. The Lucitrap® system in combination with other management changes may be part of an overall fly management program (Horton *et al*., 2001a). It is important to note that no effective suppression was found at the Malmesbury locality towards the end of the experiment (Chapter 3). At this stage it is unclear whether this end result is related to the very low *Lucilia* counts at this locality, as was also reported by Urech *et al*. (1998) and Horton *et al*. (2001a). This result, however, negatively affects the robustness of conclusions derived from the other two localities. Further research, encompassing agro-ecological regions that are distinctly different, needs to be considered seriously. This work is seen as a prerequisite for the wider application of the Lucitrap® system in the South African sheep industry.

A further cause of concern is the fact that most of the traps in the field in our study have been in use since 1998. Horton *et al*. (2001b) reported traps became less effective each year if not cleaned regularly. The old traps became darker due to staining with dead flies and the chemical lure on the translucent plastic bucket employed on the traps, influencing their efficacy. To combat this, it was recommended that the lures should be replaced every three months, and that the traps must be cleaned each year (Horton *et al.*, 2001b). A comparative study between the old traps used in the field and new ones is envisioned for the near future in South Africa.

An alternative use of the Lucitrap® system would be to monitor *Lucilia* numbers to assist the strategic decision making with regard to chemical treatment. Monitoring, by using this system, can indeed serve as an indication of the number of active flies at different times during the year, as seen in Chapters 3 and 4 as well as in the literature (Horton *et al.,* 2001a). Active flies were found at all localities throughout the year, generally with lower numbers during the warm summer months and very low numbers during the cold winter months. A definite seasonal pattern was confirmed with high activity during the spring-early summer. Depending on climatic conditions, a secondary peak was observed during autumn under certain conditions. These findings are consistent with generalizations for Southern Africa, as put forward by Howell *et al*. (1978). The relationship between blowfly numbers and weather data was rather unsatisfactory in the present study. The analysis of this relationship seems to be more intricate than allowed for by the statistical methods employed. Further work on the modeling of blowfly population dynamics for strategic decision making regarding pre-emptative management for blowfly strike, is required. Future research should take cognizance of this fact, and the development of a pro-active decision making model should be seriously contemplated.

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