Optimising the sensitivity of sheep inspection for detecting lice

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Summary
The primary means of monitoring for lice is by inspection of sheep, but there has been little consideration of ways to optimise the efficiency of detection by this method. Studies are described that confirm a strong association between pruritic behaviour, fleece derangement and the presence of lice, particularly early in the development of an infestation. These signs are a valuable aid to selecting sheep for closer inspection. The spatial distribution of lice on sheep is discussed and it is concluded that to maximise the probability of detecting lice, inspections should be concentrated on the sides of the sheep at most times of the year. However, if the sheep has been recently shorn attention should also be focussed on sites below the neck, on the lower flanks and upper legs, particularly in areas where longer wool has been left. Probabilities of detecting lice on individual sheep and in mobs by inspection regimes varying in numbers of sheep and numbers of partings per sheep are estimated for different levels of infestation. These estimates may provide an aid in developing inspection regimes to suit varying management circumstances.

Keywords
Phthiraptera, *Bovicola ovis,* detection, pruritis, behaviour

Introduction

The ability to determine if a flock is infested is pivotal to optimal louse control programs. With increasing pressure to reduce reliance on chemical methods and continuing need to reduce costs, many woolgrowers are now seeking to forego routine annual treatment in favour of treatment only when lice are found. Success of this approach relies on the ability to detect lice when they are present. Sensitive lice detection is also fundamental to preventing new infestations from purchased or agisted sheep and identifying infestations on stray sheep.

A number of systems of detecting lice have been tested including the AWTA lice detection test (Kettle and Lukies 1984; van Schie 1987), the lamp test (Morcombe *et al.* 1995) and the locks test (Morecombe *et al.* 1995) and new methods are presently being researched (Michalski *et al*., 2001). However, these systems rely on shearing the sheep for diagnosis. Presently, detecting lice in time to make treatment decisions at shearing depends almost exclusively on sheep inspection. In addition, when new sheep are introduced to a property, or stray sheep are found in the mob, they will not generally be shorn and detection of lice will depend on inspecting the immigrant animals.

In the early stages of an infestation only a few sheep in the mob will have lice and numbers of lice on the infested animals are likely to be low. Detecting lice if they are present depends firstly on selecting an infested sheep for inspection and secondly finding lice on that animal.

This paper addresses ways of maximising the sensitivity of detecting lice given that a finite amount of time and effort is available.

Three main questions must be answered:
(a) Which sheep should be chosen for inspection?
(b) Which sites on the sheep's body should be inspected?
(c) How many partings per sheep and how many sheep in a mob should be inspected?

Which sheep should be inspected?

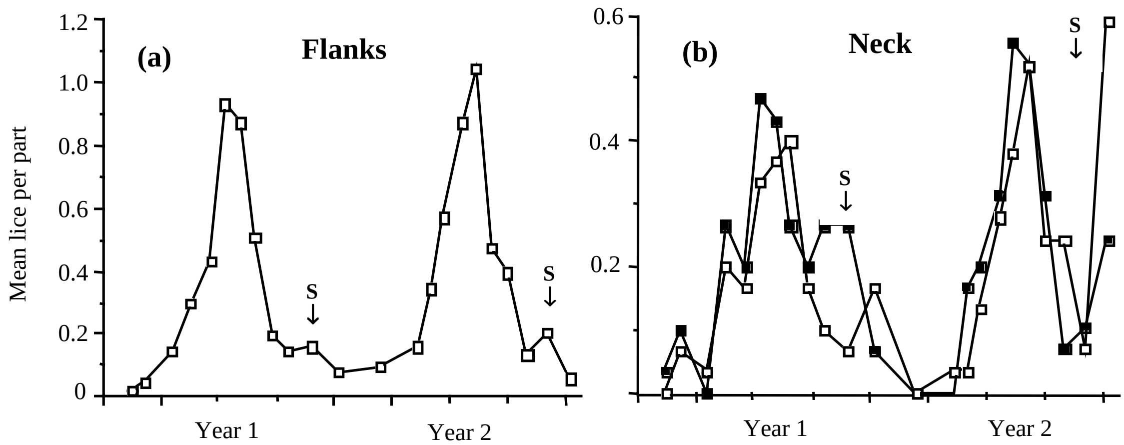
Selecting sheep on the basis of pruritic behaviour or deranged fleece

Observation of sheep rubbing or biting at their wool and the presence of sheep with deranged fleeces are two of the most common methods used by sheep owners to diagnose lice (Pearse and Baldock 1994). However, it is commonly noted that rubbed wool is a poor indicator of infestation (Pearse and Gardner 1994) and that there is a poor relationship between deranged fleece and louse numbers. Sinclair *et al.* (1989) cited preliminary data that suggested a lack of direct association between louse numbers and the intensity or duration of rubbing, scratching or biting. However, more recent studies (James and Moon 1999; James and Karlsson unpublished) suggest that there may be a closer relationship between pruritic behaviour, fleece derangement and louse numbers than previously believed. These experiments are described below.

Association between louse infestation and pruritic behaviour

James and Moon (1998) investigated the relationship between louse numbers and pruritic behaviour in Polypay and Columbia ewes. Twelve of each breed were artificially infested with 35 lice on two occasions a month apart and again with 20 lice, 13 months later. The other six of each breed remained uninfested. The animals were confined in groups of three of similar breed and infestation status in spatially separated pens and lice counted at 69 sites on each animal at approximately monthly intervals. Pruritic behaviour was scored on each sheep in four, 10 minute sessions (morning, afternoon, evening and at night) the day before each louse census. Discrete pruritic events were recorded as rubbing, biting or scratching and the body region to which pruritic behaviour was directed (neck, sides/flank, shoulder/front leg, rump/backleg or peripheral) was noted. Peripheral sites included areas where lice were not commonly found (belly, hocks, feet, face and ears).

Figure 1. Changes in louse densities on the (a) flanks and (b) left (—■—) and right (—□—) sides of the neck over two years.



Louse populations increased from initial infestation in autumn to a peak in spring and then declined until late summer (Fig. 1(a)). There were clear differences between the two breeds, with Polypays having approximately ten times more lice than Columbias at most inspections (James *et al.* 1998). Seven of the Columbias and one of the Polypays did not develop persistent infestations. It should be noted that the densities of lice on the sheep in this study were relatively low and even at the peak, the mean count per part on the sides of the sheep was only about one louse per part.

Pruritis was correlated with numbers of lice in the infested Polypays in both years. The correlation over all inspection times was 0.72 ($p < 0.001$) in the first year and 0.65 ($p = 0.001$) in the second. Although increases in pruritis coincided with increases in louse numbers in the infested Columbias, the association was not significant in 1995 ($r = 0.27$, $p = 0.398$) or 1996 ($r = 0.14$, $p = 0.665$). This is probably due to the very low numbers of lice on the Columbias. When the association was examined within inspection times, there was no correlation between lice and pruritis at the first inspection one month after initial infestation, when densities were lowest. However, at the inspection at seven weeks after infestation the correlation rose to 0.395 ($p = 0.056$). At this time the total count of lice was only 18 on 11 infested sheep. At 12 weeks the correlation was 0.645 ($p < 0.001$) and thereafter there were significant positive correlations ($p < 0.05$) at all inspections except for those close to shearing when louse densities were low.

Table 1 summarises the frequencies of the different pruritic behaviours observed and the body sites to which they were directed. Over the period of the study, 51% of pruritic activity in the infested groups involved the sides of animals, which was also where most lice were found (Table 2). The majority of pruritis was biting, although sheep also commonly rubbed their sides against fixtures in the pens.

Some behaviours seen in infested sheep were uncommon in animals with no lice. These included pruritis directed to the neck and foreleg and sheep scratching with their hindlegs at sites low on the flanks. Although these behaviours may also be stimulated by agents other than lice, they might provide a more reliable indication of louse infestation than overall pruritic activity.

Table 1. Mean number and type of pruritic events directed to different body regions in naive and infested Polypay ewes during 40 minute observation periods.

	Neck		Foreleg		Sides		Hindleg		Peripheral		Overall	
	N[a]	I[a]	N	I	N	I	N	I	N	I	N	I
Scratch	0.01a	0.19b	0.00	0.07	0.00a	0.12b	0.00	0.00	0.27	0.29	0.28a	0.68b
Rub	0.00	0.09	0.00	0.08	0.16	0.46	0.04	0.06	0.10	0.09	0.30	0.77
Bite	0.00	0.01	0.03	0.14	0.14a	0.63b	0.02	0.04	0.14	0.09	0.34a	0.92b
Total	0.01a	0.29b	0.03a	0.29b	0.30a	1.21b	0.05	0.07	0.51	0.48	0.92a	2.37b

[a] N = naive; I = Infested

[b] Means for naive and infested sheep within region and behaviour followed by different letters are significantly different, $p < 0.05$; $n = 24$.

Even though the experiment indicated a significant association between pruritic activity and louse numbers, pruritis was often episodic and there were many observation periods when sheep known to be heavily infested showed no pruritic activity. There were also instances of pruritic behaviour in sheep with no lice. Sheep were observed more intensively in this study than would be feasible in most practical situations. In addition, they were continually confined indoors in pens and were not exposed to the range of pruritic agents potentially present under field conditions (Johnson *et al.*, 1993). Therefore, although there was a clear relationship between pruritic behaviour and louse numbers, observation of pruritic behaviour may not be a practically useful indicator of *B. ovis* infestation under many circumstances.

Association between louse infestation and deranged fleece

A moderately infested sheep with a mean louse count 4.1 per part was introduced into a mob of 32 uninfested 18 mth old merino ewes with 10 weeks wool for 15 weeks. At the end of this period the infestor sheep was removed and the infestation allowed to develop in the remaining sheep. All sheep were scored for fleece derangement by two independent observers using the following scoring system: 0 - no rub; 1 - suspect, not sure; 2 - light but obvious rub, fluffy tip or definite pulled fibres at some sites; 3 - distinct but dispersed pulled strands (thicker than fluffy); 4 - definite patches or areas of pulled strands, < than 20% of fleece affected; 5 - definite patches or areas of pulled strands, > than 20% of fleece affected; 6 - grossly matted fleece +/- areas rubbed bare. Following scoring for fleece derangement, lice were counted in 10 cm wool parts at 24 sites on all sheep.

Figure 2 shows the spread of lice through the flock and build up in louse numbers after the introduction of the infestor sheep. At 6 and 9 weeks after introduction 6% and 25% of sheep were found with lice and the mean counts per part on the infested sheep were 0.06 and 0.04. At 15 weeks the infestation was still light, but by week 22 the rate of louse build up had reached the exponential growth phase. Even though louse numbers were quite low at 15 weeks, lice were detected on 40% of sheep and by 22 weeks nearly 80% of sheep had lice.

Figure 2. Changes in (a) the percent sheep infested and (b) mean louse numbers per part in a Merino flock following the introduction of one infested sheep at week 0.

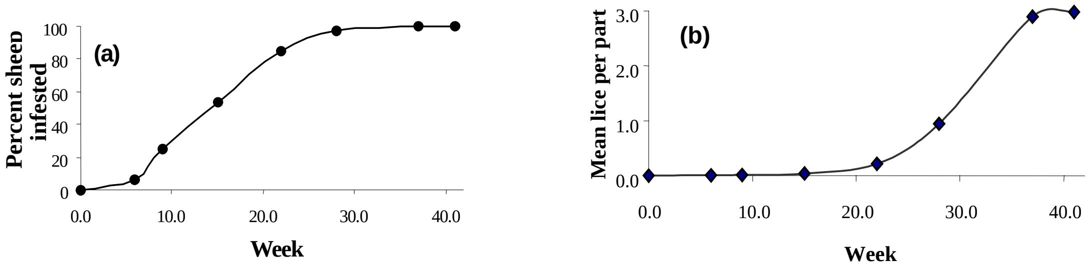
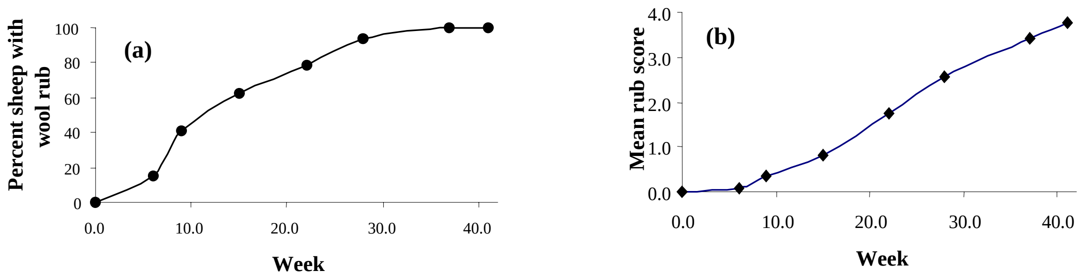


Figure 3. Changes in (a) the percent sheep with fleece derangement score greater than 0 and (b) mean derangement score in a Merino flock following the introduction of one infested sheep at week 0.



Increase in fleece derangement score followed the pattern in percent of sheep infested (Figure 2). At week 15, 63% of sheep had some degree of wool rub and the maximum score was 2.5, but by week 22 all sheep had some wool rub and the maximum score was 5. This approximates the rule of thumb that it takes about 4 months after the initial contact with other lousy sheep for an infestation to become apparent. There was a clear correlation between louse numbers and wool rub from week 9 onwards, with the exception of the last inspection at 41 weeks (Table 2). At 9 and 15 weeks the mean (maximum) densities of lice found on individual sheep were 0.05 (0.08) and 0.06 (0.33) per part respectively. The strength of the correlation decreased once all sheep were infested. This agrees with the observations of James and Riley (unpublished) who found a relatively low correlation of 0.3 in a flock which had been infested with lice for three years. Once most sheep have become infested one might expect intrinsic sheep differences to play a more important part in determining the degree of pruritic behaviour and fleece derangement than numbers of lice *per se*. It is also possible that fleece derangement score is not a good reflection of louse numbers at higher louse densities and that a stronger correlation exists between the frequency of pruritic behaviour and louse numbers in advanced infestations.

Table 3 shows the effect of preliminary selection on the basis of wool rub on the likelihood of detecting lice. For example, if sheep had been selected on the basis of a fleece derangement score of one or greater at week 6 the proportion of infested sheep in the sample would have increased more than three fold from 6% in a random sample to 20% in the selected sample and the mean density of lice would have increased by more than five times from 0.003 to 0.017 per part. Thus selecting on the basis of wool rub markedly increased both the likelihood of choosing a sheep with lice for inspection and of finding lice when the sheep was inspected. The gains were greatest in the early stages of an infestation, which is when detection is most important. Even though the gains became smaller as the infestation developed, the probability of choosing an infested sheep and of finding the lice on the selected animal was always greater if sheep with fleece derangement were chosen for inspection. The data also suggest that there is a relatively good association between numbers of lice and the degree of wool rub (except possibly in mobs with heavy infestations) and that selecting the sheep with the most marked derangement will increase the probability of detection (Table 2).

Table 2. Correlation between fleece derangement score and louse count at different times after the introduction of a lousy sheep to a mob of 32 Merino wethers.

Weeks after introduction of the infested sheep	Percent sheep infested	Mean count per part of infested sheep	Correlation between fleece derangement score and louse count
6 wks	6	0.05	0.26
9 wks	25	0.06	0.44*
15 wks	53	0.09	0.40*
22 wks	84	0.29	0.79***
28 wks	97	0.97	0.63***
37 wks	100	2.90	0.49*
41 wks	100	2.98	0.12

*P<0.05; **P<0.01; ***P<0.001

Many factors can cause sheep to rub (Johnson *et al.* 1993) and the presence of rubbing sheep or deranged fleece is not necessarily indicative of lice. Where rubbing sheep are present, sheep must still be inspected and lice must be found for an infestation to be diagnosed. However, indications to date are that sheep are relatively sensitive to the presence of lice and begin to exhibit pruritic behaviour and deranged fleece sooner after initial infestation than previously suspected. Studies are presently under way to clarify the temporal relationship between infestation and the development of these signs. It may also be possible to use fleece derangement as a tool to identify infested sheep for treatment, or removing infested sheep from a mob to slow the spread of an infestation. This is the topic of a further paper (James, Karlsson and Campbell, these proceedings).

Table 3. Improvement in detecting lice from selecting sheep on the basis of fleece derangement

	Assessed positive on the basis of fleece derangement score						
	Week 6	Week 9	Week 15	Week 22	Week 28	Week 37	Week 41
Unselected mob							
% infested sheep	6.25	25.0	53.1	84.4	96.9	100	100
Mean lice/ 10cm fleece part	0.003	0.011	0.037	0.217	0.944	2.897	2.977
Sheep selected on wool rub score							
Sheep with score ≥ 1							
% sheep selected	15.6	40.6	62.5	78.1	93.8	100	100
% selected sheep with lice	20	46.2	65	96	100	100	100
Mean lice/ 10cm fleece part	0.017	0.022	0.05	0.27	0.997	2.897	2.977
Sheep with score ≥ 2							
% sheep selected	0	6.25	15.6	56.3	71.9	100	100
% selected sheep with lice	-	100	60	100	100	100	100
Mean lice/ 10cm fleece part	-	0.042	0.133	0.345	1.197	3.170	2.977

Selecting sheep with poor body condition for inspection

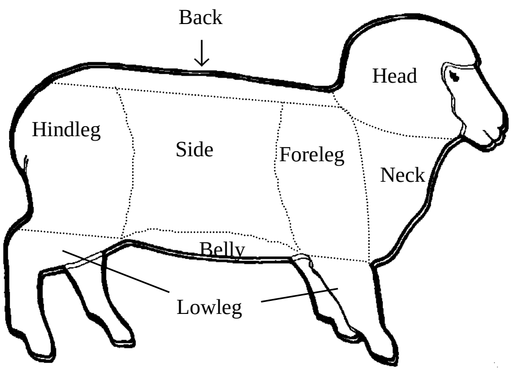
It is a common observation amongst sheep owners that sheep in poor condition tend to have heavier infestations of lice than those in good condition. James *et al.* (1998) found that louse counts on lambs from birth until sale were negatively correlated with overall weight gain (r_p = -0.64, p = 0.018). Between weaning and sale the correlation was -0.77 (p = 0.013). In addition, Scott (1952) showed that populations of *B. ovis* increased during winter on crossbred sheep on a low nutritional plane, but not on sheep with high nutrition. Interestingly, there was no effect of nutrition on louse numbers on Merinos. There is a widespread belief that lice cause differences in weight gain, but studies designed to measure the effects of lice on body weight have regularly shown no effect (Kettle and Lukies 1982; Wilkinson *et al.* 1982; Niven and Pritchard 1985). James *et al.* (1998) suggest that animals in poor condition may be more susceptible to lice because of an impaired ability to mount a regulatory response caused by the stress of disease or poor nutrition. Heath *et al.* (1996) also cite preliminary data which indicated an association between louse numbers and body condition and suggest that low bodyweight animals may be the most likely to sustain the largest louse infestations. However, it should be kept in mind that although these animals may be more likely to have high numbers of lice if they have been exposed to infestation, this increased susceptibility can only be manifest if they have contacted another lousy sheep. They are therefore not necessarily the most likely to be positive to lice in the early stages of an infestation.

Detection of lice on individual sheep

Where to look for lice

To determine the distribution of lice on sheep through the year, lice were censused at the 69 sites in the body regions shown in Figure 3 at approximately monthly intervals over two years. The relative densities of lice in different body regions on sheep with 8 months wool are shown in Table 4

Figure 3. Body regions where lice were counted.



Changes in the densities of lice in the different body regions through the year are described in detail by James and Moon (1999). The distribution of lice for most of the year was similar to that given in Table 4, with louse density highest along the sides. Thus likelihood of detecting lice is maximised at most times by concentrating inspections on the sides of sheep. Shearing markedly reduced density in most body regions, but increased the proportion of lice found low on the flanks, on the neck, belly and upper legs (Fig. 1(b)). Therefore, when inspecting recently shorn sheep for lice, more attention should be given to sites around the neck and low on the flanks, particularly in areas where longer wool has been left.

How many parts to inspect?

Once a sheep with deranged fleece has been selected, or perhaps a stray sheep has been found in the mob or returned from neighbours, the question becomes how many parts to inspect to determine whether or not the animal is infested. There is no easy answer as clearly this depends on how many lice are present. The number of parts inspected also depends on the situation in question and the individual growers attitude to risk.

Table 4. Relative densities of lice in different body regions in sheep with eight months wool

Body Region	Relative density of lice (Density on sides set to 1.0)
Sides	1.0
Back	0.69
Foreleg/shoulder	0.46
Neck	0.45
Hindleg	0.37
Belly	0.26
Head	0.20
Lowleg	0.10

Source: James and Moon (1999)

Table 5 gives the probability of detecting lice with different numbers of parts inspected on sheep with different numbers of lice present. In the early stages of an infestation when there are no signs of lice the more parts that can be inspected the greater the likelihood of detecting lice.

For example, at a density of 0.05 per part increasing the number of parts from 10 to 20, from 20 to 40 and further gives approximately linear increases in the probability of detection. However, at higher louse densities there is less gain in sensitivity from inspecting large numbers of parts. For example, on sheep with a louse density of 0.5 per part increasing the number of parts inspected from 10 to 20 only increases the probability of detection by 0.05. This is very inefficient in terms of the effort expended. Where more than one rubbed or stray sheep is available for inspection, the better option appears to be to choose more sheep rather than to conduct a very intensive search on one animal. This theme is developed further in the next section.

Table 5. Probability of detecting lice with different numbers of parts on individual sheep with different levels of infestation.

Mean lice per part	No. parts per sheep	Probability of detection	Mean lice per part	No. parts per sheep	Probability of detection
0.005	1		0.5	1	0.25
(ca. 15 lice per	5	0.02	(ca. 1500 lice	5	0.77
sheep)	10	0.05	per sheep)	10	0.95
	20	0.09		20	1.00
	40	0.18		40	1.00
0.05	1	0.05	1	1	0.36
(ca. 150 lice per	5	0.21	(ca. 3000 lice	5	0.89
sheep)	10	0.37	per sheep)	10	0.99
	20	0.60		20	1.00
	40	0.84		40	1.00
0.25	1	0.17	5	1	0.58
(ca. 750 lice per	5	0.60	(ca. 15000 lice	5	0.99
sheep)	10	0.84	per sheep)	10	1.00
	20	0.97		20	1.00
	40	1.00		40	1.00

Source: James, Moon and Garret (*in press*)

The other point to note is the difficulty of detecting lice in newly infested sheep. For example, at a louse density of 0.05 or approximately 15 lice, even with 40 parts per animal the probability of detection is only 0.18. The difficulty of detecting lice at low louse densities represents a significant difficulty for keeping flocks lice free on properties where sheep are regularly purchased and underlines the desirability of quarantining newly purchased animals.

Inspecting for lice in mobs

The probability of detecting lice in a mob is a combination of two things, the probability of choosing an infested sheep and the probability of finding lice on that sheep. Using computer modelling we considered the probability of detection under a number of different scenarios of mob size, percent sheep infested and different densities of lice on the infested animals (James, Moon and Garrett, in press).

Figure 3. Probability of detecting lice by inspecting different numbers of sheep and different numbers of parts per sheep in flocks with 10% or 50% of sheep infested and louse densities of 0.05, 0.25 and 1.0 lice per part.

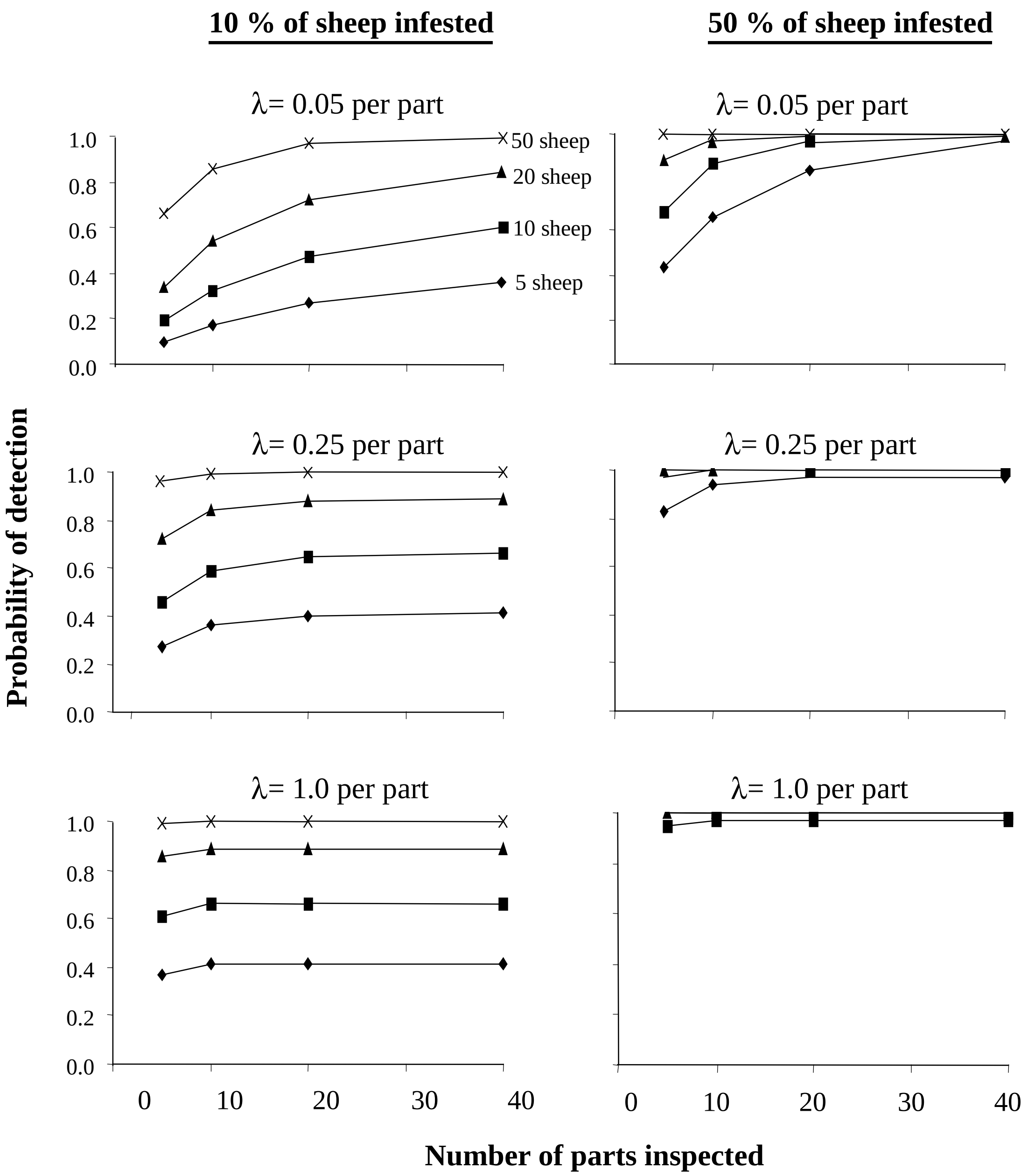


Figure 3 gives the probability of detecting lice in mobs with 10% and 50% of sheep infested at louse densities of 0.05, 0.25 and 1 louse per part, with different numbers of sheep and different numbers of parts per sheep selected. From these graphs it is apparent that increasing the number of sheep inspected increases the probability of detection more than increasing the number of parts by an equivalent number. This advantage is greatest in situations where there is a low percentage of infested sheep in the mob, but where the infested sheep have high louse density. At lower louse density and higher percentages of the flock infested the gain from increasing the number of sheep in comparison to increasing the number of parts was smaller, but still apparent.

However, the foregoing discussion assumes that the effort to select another sheep is equivalent to that for an extra fleece parting. The relative effort involved in choosing a new sheep compared to inspecting another part on the same sheep will vary in different situations and allowance will need to be made for this. In addition, different woolgrowers will accept different levels of risk in terms of infestation and may vary the rigour of inspection accordingly. For example, a certified organic grower will have a much greater stake in preventing the introduction of lice and avoiding treatment than a producer who is simply aiming to reduce costs. The level of sensitivity required may also vary with the time until the next shearing and the consequent potential for wool losses to occur. The probability functions in Figure 3 may assist the choice of inspection regimes to suit different situations.

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