INVESTMENT ANALYSIS OF REPLACING ENDOPHYTE-INFECTED WITH ENDOPHYTE-FREE TALL FESCUE PASTURES

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ABSTRACT

Cattle consuming tall fescue pastures infected with the endophyte *Neotyphodium coenophialum* often suffer physiological disorders that reduce animal performance. One solution is to replace endophyte-infected tall fescue pastures with an endophyte-free mixture. A benefit-cost analysis was conducted to determine the profitability of pasture restoration. The profitability of this action depends on the percentage of endophyte in existing pastures, the discount rate, and the stand life of the endophyte-free tall fescue variety. Our benefit-cost analysis results indicate that in order for pasture replacement to be profitable, the existing pastures must be infected with more than 16.1% of the endophyte, assuming the stand life of endophyte-free tall fescue is 12 years and the discount rate is three per cent. Additionally, a sensitivity analysis was conducted to determine the impact on the critical infestation level when the following parameters are changed: the discount rate, the baseline calving rates, and the pasture stand life. This research provides farmers with a practical investment analysis model for replacing endophyte-infected with endophyte-free tall fescue pastures.

INTRODUCTION

Tall fescue (*Festuca arundinacea = Lolium arundinaceum*) is commonly used for beef cow/calf production (Hoveland, 1997), occupying nearly 25 million acres in the southeastern and east-central regions of the United States (Hannaway, 1999). Although tall fescue is a well-adapted pasture grass in the U.S., it has a reputation for poor performance by grazing livestock because of the presence of the fungal endophyte, *Neotyphodium coenophialum* (Lomas et al., 1999). Animals grazing on tall fescue infected with this endophyte often develop physiological disorders that reduce animal performance and profitability. Poor cattle performance is exemplified by reduced weight gains, lower milk production, poor conception rates, and lengthened gestation terms (Waller, 2002; Hemken et al., 1979). The U.S. economic loss associated with this endophyte for beef was estimated at over $600 million (Hoveland, 1993).

Economic losses from animals consuming tall fescue have led to the introduction of endophyte-free tall fescue varieties to replace the stands containing the endophyte (Ball, 1992). Stands of endophyte-infected tall fescue persist for many years because the fungus *N. coenophialum* is maintained in the host plant’s aerial tissues, vegetative propagules and nearly 100% of its seeds (Siegel, 1989). Fortunately, the endophyte has no means to spread contiguously. Once the endophyte-free stand is established it should remain endophyte-free unless endophyte seeds are introduced (Ball et al., 2003).

However, endophyte-free tall fescue is not as tolerant to overgrazing, drought, and other stresses as endophyte-infected tall fescue (West et al., 1988). Greenhouse studies confirmed the enhanced drought tolerance of the endophyte-infected tall fescue due to the presence of the endophyte (Arachevaleta et al., 1989). Also, endophyte-free varieties are more susceptible to certain herbivorous insects, parasitic nematodes, and pathogenic fungi (Jeger, 1999). Researchers have experienced difficulties establishing endophyte-free stands, particularly under conditions such as the drought of 1988 (Chestnut et al., 1991). Thus, although the endophyte-free tall fescue is better for the health of grazing animals and their ultimate economic profitability, the persistence of endophyte-free tall fescue is not as hardy as endophyte-infected tall fescue.

The effect of the endophyte on stand persistence has not previously been incorporated into benefit-cost analysis for stand replacement. Published benefit-cost analysis also does not take into account endophyte effects on animal fertility. There is increasingly strong evidence that the presence of the endophyte in tall fescue pastures adversely affects pregnancy rates in cattle and other livestock. For example, conception rates of 67% were reported for cows grazing on tall fescue pastures with a high concentration of endophyte infection, compared to 86% for pastures with low concentration (Gay et al., 1988). Danilson et al. (1986) reports a 43% difference in pregnancy rates of cattle consuming low- versus high-endophyte-infected tall fescue pastures.

This research presents an investment analysis of renovating existing endophyte-infected pastures with an endophyte-free variety of tall fescue. Our research builds upon literature of prior economic analysis by using updated information concerning endophyte effects on animal fertility and persistence of the tall fescue stand. Empirical results of this research contribute to the literature by identifying economic management strategies that have not been previously assessed. These results are particularly important due to the widespread use of tall fescue and the extensive economic losses associated with animals grazing on tall fescue infected with the endophytic fungus *N. coenophialum.*

MATERIALS AND METHODS

Costs of Pasture Reestablishment with Endophyte-free Tall Fescue

The costs of reestablishing pastures include the initial investment, which involves destroying existing pastures, planting corn, and sodseeding with an endophyte-free-clover variety. Other costs include maintenance costs, which are costs incurred after the initial investment.

Table 1 lists the initial investment during the first year. This includes the costs for destroying existing stands and reestablishing pastures with clover and non-infected fescue. In Table 1, each acre is charged an expense for destroying the existing fescue with two applications of the herbicide paraquat. Corn to be used for silage is then planted as a rotation crop to ensure infected plants will not emerge into new fescue stands. Based on farmers' opportunity cost associated with pasture renewal, each acre is charged for pasture rent while corn is planted--farmers must either move their cattle to alternative pastures, buy more feed, or raise their stocking rates on non-renewed acreage. Since pastures are to be seeded with non-infected fescue and clover in the fall, the corn must be harvested and stored before fall arrives. Therefore, the costs of planting, harvesting, and storing silage are included in this analysis along with the silage value, which will either be sold or used by the producer. The value of corn silage is $22 per ton (Trimble et al., 2000), assuming a yield of 14 tons of silage per acre (Standaert, 1987).

Maintenance costs are upkeep costs associated with reestablishing the endophyte-free fescue/clover pasture. For example, maintenance costs include fertilizer and lime applications. Table 2 outlines these costs, which assume the clover stand life is 3 years. All data have been inflated to 2002 dollars.

Savings from Pasture Reestablishment with Endophyte-free Tall Fescue

Given the above costs, our attention now focuses on the benefits of reestablishing pastures with endophyte-free tall fescue. There are two kinds of benefits, gross returns (gr_i) and reestablishment savings (fs_i), described below.

Standaert (1987) decomposed the gross returns (gr_i) per acre for each infestation level i into four parts: the sales income from steers (s), heifers (h), cull cows (c), and replacement heifers (r). We define w_{si}, w_{hi}, w_{ci} and w_{ri} as the ending weights for each of these four animal types, respectively, at infestation level i. We next define p_s, p_h, p_c and p_r as the price per pound for each of these four respective animal types.

Then we define c_i as the baseline calving rates at infestation level i. And c_{ci}=(1- c_i) represents the cull cows group. Thus $c_{ci} + c_i$=1 cow unit. Then we define r_i as the replacement rate at infestation level i. Relationships among the baseline calving rates (c_i), the replacement rate (r_i), and the proportion of steers (c_{si}), heifers (c_{hi}) and replacement heifers (c_{ri}) per cow unit at infestation level i are described in Figure 1 and as follows:

(1) $c_{si} = 0.5 * c_i$, whereby half of new-born calves are assumed male (c_{si}) and half female.

(2) $c_{hi} = 0.5 * c_i - r_i$, identifies the heifer group after subtracting heifers used for replacement (r_i).

(3) $c_{ri} = r_i – c_{ci}$, identifies the replacement heifer group for sale after subtracting the heifers used for replacement.

Following Schmidt’s research, we assume that the baseline calving rates (c_i) equaled 90%, 82%, 55% when the infestation level ranged from 0% to 20%, from 30% to 70%, and from 80% to 100%, respectively. We also assume the replacement rate (r_i) equaled 15%, 20%, and 25% when the infestation level equaled to the above ranges, respectively.

We next define s_i as the season average stocking rates, i.e., the number of cows per acre at infestation level i. Thus, the gross returns per acre for each infestation level may be calculated as the sum of sales income from these four animal types. Considering that the sales income for each animal type is obtained by multiplying its ending weight (w_{li}), price (p_l), proportion per cow unit (c_{li}) and the stocking rates (s_i), the total gross returns per acre at infestation level i is calculated as

(4) $gr_i = \sum w_{li} * p_l * c_{li} * s_i$, for each animal type $l = s, h, c, r$ at infestation level i.

Given various infestation levels i, w_{li}, c_{li} and s_i are specified in Table 3. Using the 2000 Livestock Budget Estimates (Trimble, 2000), the prices for the four animal types are assumed \$1.10, \$1.01, \$0.42 and \$1.01 per pound, respectively, after being inflated to 2002 dollars. Gross returns per acre (gr_i) at infestation level i are computed and also listed in Table 3.

The formula for determining reestablishment savings per year quoted from Standaert follows:

(5) $fs_i = (gr_{-30} - gr_i) + (s_i - s_{-30}) * CP$,

where *CP* is per head charges which include marketing, labor and management, veterinarian costs, interest and depreciation, and miscellaneous expenses. The variable CP=\$185.78 in this research. The variables fs_i, gr_i, and s_i are the reestablishment savings, gross returns and stocking rates, respectively, at infestation level i. Negative infestation levels represent the addition of clover to a clean fescue pasture (Standaert, 1987). Using equation (5), reestablishment savings (fs_i) were calculated and listed in Table 3.

Net Present Value and Standaert's Model

The Net Present Value (NPV) of the costs and returns for the investment to replace the endophyte-infected pasture with endophyte-free tall fescues at a specific discount rate (d=0.03) and specific pasture stand life (N=12) follows:

(6) $NPV_i = -I_0 + \sum_{t=1}^{N} \frac{fs_i + mc_t}{(1+d)^t}$,

where I_0 is the initial investment ($404.70, as identified in Table 1) during the first year, and mc_t is the maintenance cost savings at year t (mc_t =$-75.09 for t= years 3,6,9, and 12, and mc_t =$56.69 otherwise, as identified in Table 2).

A two-point-linear-interpolation method was then used to approximate the critical infestation level (I_{cr}) where *NPV* is zero. That is

$$(7)\quad I_{cr} = I_{i1} + \frac{0-(NPV_{i1})}{NPV_{i2}-(NPV_{i1})} * (I_{i2} - I_{i1}),$$

where I_{i1} and I_{i2} are the two contiguous infestation levels (%) with $NPV_{i1} < 0$ and $NPV_{i2} > 0$, respectively.

Therefore, the criteria for pasture restoration is the following: *If the current infestation level is greater than* I_{cr} *, then it will be profitable to replace endophyte infected tall fescue pastures with an endophyte-free mixture.* Table 4 lists the net present values (NPV) in dollar terms and the critical infestation levels (I_{cr}) in percent for reestablishing pastures with a fescue-clover mixture at various infestation levels. Results are discussed below.

Sensitivity Analysis

A sensitivity analysis was conducted to provide more information to farmers. The profitability of reestablishing pastures with an endophyte-free variety of tall fescue and clover depends upon several factors. Our sensitivity analysis was conducted by altering individual variables, while holding others constant. The variables altered in this sensitivity analysis were the discount rate, baseline calving rates, and the stand life of the endophyte-free fescue.

For our baseline analysis, a discount rate of 0.03 was used to calculate the net present value with results presented in Table 4. Theoretically, raising the discount rate would lower the NPVs and therefore change the critical infestation level (I_{cr}). A discount rate of 0.05 and 0.10 were used in this sensitivity analysis to determine the effects on the NPV and the I_{cr} .

Baseline calving rates were increased 5% ($c_i^* = 1.05 * c_i$) in this sensitivity analysis. Gross returns per acre (gr_i) and reestablishment savings per year (fs_i) were recalculated accordingly and thus new values of NPV and I_{cr} were derived. A pasture stand life of 12 years was used in our baseline analysis. For our sensitivity analysis, 15 and 9 years, respectively, were used to determine the effect of the pasture stand life on NPV and I_{cr} .

RESULTS AND DISCUSSION

Cattle producers' management options regarding pasture replacement of endophyte-infected with endophyte-free tall fescue pastures must base their decisions on the net present value for these options. According to the above formulas used to calculate NPV and the critical infestation level (I_{cr}), if the percentage of endophyte in pastures is below 16.1%, then pasture replacement is not economically profitable as shown in Table 4. However, if the percentage of endophyte in existing pastures exceeds 16.1%, then reestablished endophyte-free tall fescue pastures would generate greater returns annually compared to taking no action.

In our baseline analysis, we assume (1) the discount rate is 0.03; (2) the baseline calving rates equal 90%, 82%, and 55% when the corresponding infestation level range is 0% -20%, 30%-70%, and 80%-100%, respectively; and (3) the pasture stand life is 12 years. In our sensitivity analysis, we adjust each of the three variables independently. After we increase the discount rate from 0.03 to 0.05 and 0.10, respectively, we find that the net present value decreases in both cases and that the critical infestation level increases to 20.2% and 22.2%, respectively. After we increase the calving rates by 5% (i.e. the calving rates now equal 94.5%, 86.1%, and 57.5%, respectively when the infestation level range is 0% -20%, 30%-70%, and 80%-100%, respectively), net present value increases and the critical infestation level decreases to 13.7%. Finally, we adjust the pasture stand life from 12 years in base analysis to 9 years and 15 years, respectively. When the pasture stand life is reduced to 9 years, the net present value decreases and the critical infestation level increases to 21.4%. When the pasture stand life is increased to 15 years, the net present value increases and the critical infestation level decreases to 6.2%. Results from this sensitivity analysis are listed in Table 5 and also shown in

Figure 2.

CONCLUSIONS

Our investment analysis indicates that in order for producers' investment in reestablishing pastures to be profitable, existing tall fescue pastures must be infected by /more than 16.1% of the endophyte *Neotyphodium coenophialum*. Since infestation levels are typically greater than 25%, this result implies that pasture replacement should be profitable compared with doing nothing. Additionally, changing the discount rate, baseline calving rates and pasture stand life generate new net present values and critical infestation levels, respectively, which also indicate the cost advantage of pasture restoration compared with doing nothing. These results provide valuable information to farmers that could help them make planting decisions for pastures infected with this endophyte.

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Figure 1. Calving rates diagram

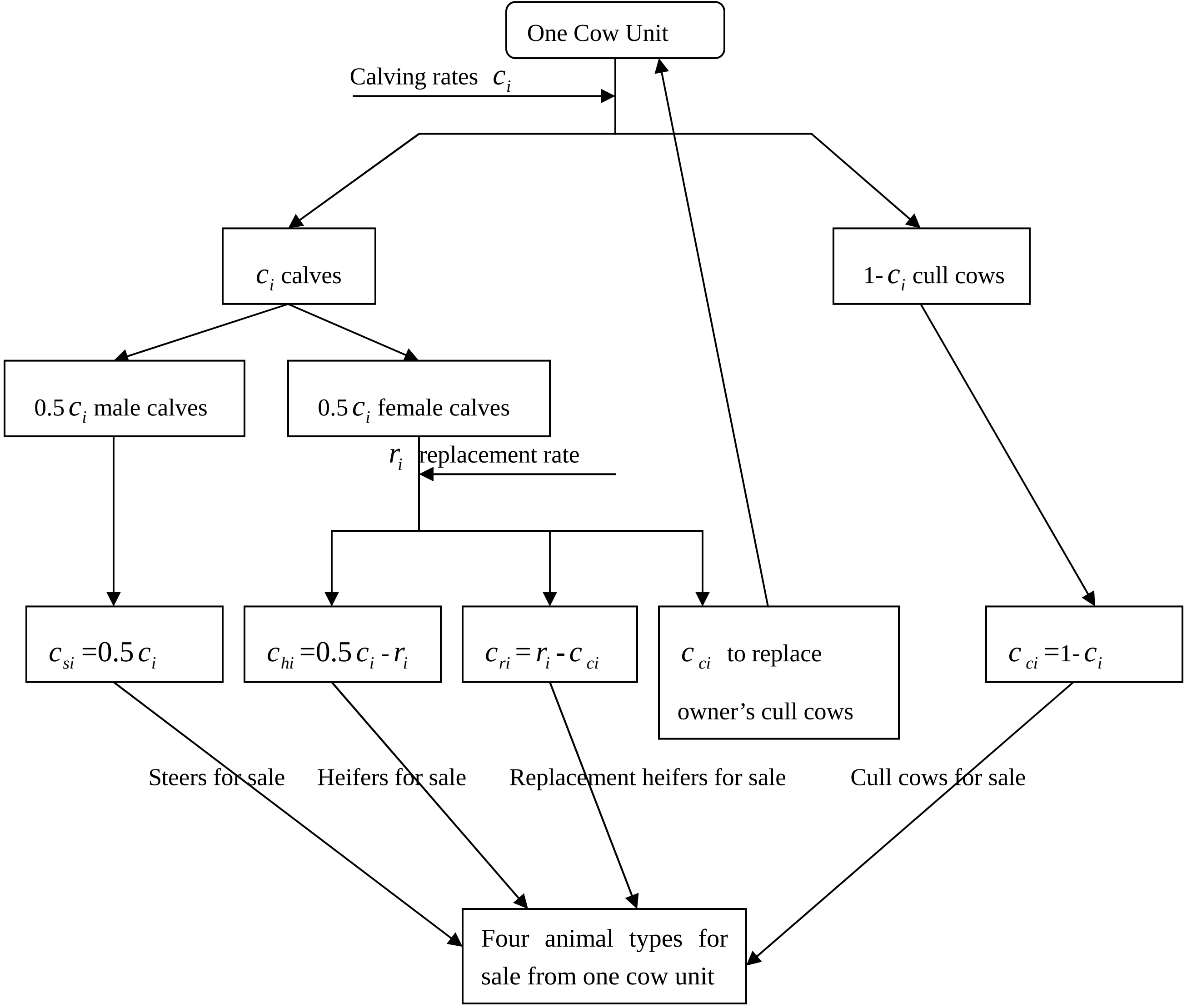

Figure 2. Relationship between Net present value and infestation level

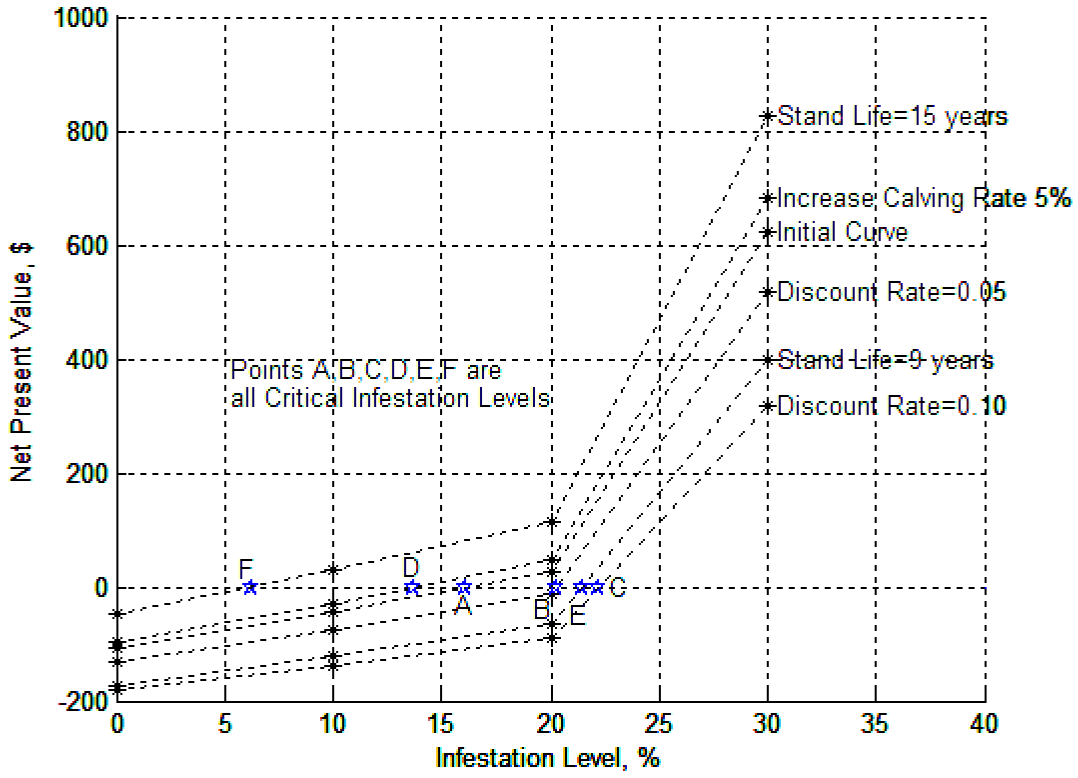

Table 1. First year investment costs for reestablishing pastures with endophyte-free fescue and clover.

Season	Actions	Cost ($ per acre)
Spring	Destroy fescue	46.02
Apr-June	Plant corn	264.66
	Pasture rent	19.02
	Interest	23.07
Total spring cost		**352.77**
Summer	Pasture rent	12.55
Jul-Aug	Interest	.51
	Harvest & store corn silage	209.19
Total summer cost		**222.25**
Fall	Sodseed clover & endophyte-free	299.02
Sept-Oct	Pasture rent	12.55
	Interest	6.23
Total fall cost		**317.80**
Total cost		892.82
Silage value		488.11
Net renewal cost		**404.70**

Table 2. Annual reestablished pasture maintenance cost savings compared to existing pasture.

	Classification	Reestablished pastures ($ per acre)	Existing pastures ($ per acre)	Cost savings ($ per acre)
For the years:	0-10-20 Bulk fertilizer	76.88		
1,2,4,5,7,8,10,11…	Tractor fuel and Lube	4.18		
	Tractor repair	1.58		
	Machinery Repair	.94		
	Totally annual operating costs	83.58	140.27	**56.69**
For the years:	Lime every three years	129.70		
3,6,9,12…*	Renovation of clover every three years	150.49		
	Total triennial maintenance year costs	280.21	205.12	**-75.09**

*: Clover stand life is assumed 3 years.

Table 3. Annual fungus savings and gross returns per acre of reestablishing pastures at various levels of endophyte infestation.

Infestation level (%)	Ending weight for four animal types* (pound)	Proportion per cow unit for four animal types (%)	Stocking rates s_i (head per acre)	Gross returns gr_i (\$ per acre)	Reestablishment savings fs_i (\$ per acre)
	$(w_{si}, w_{hi}, w_{ci}, w_{ri})$	$(c_{si}, c_{hi}, c_{ci}, c_{ri})$			
-30**	(654,590,1000,910)	(45,30,10,5)	0.80	451.87	0
-20	(632,567,1000,889)	(45,30,10,5)	0.83	453.79	3.66
-10	(610,547,1000,867)	(45,30,10,5)	0.86	455.33	7.69
0	(589,526,1000,846)	(45,30,10,5)	0.88	450.91	15.82
10	(567,504,1000,824)	(45,30,10,5)	0.91	450.03	22.28
20	(546,482,1000,802)	(45,30,10,5)	0.94	448.52	29.37
30	(524,461,1000,781)	(41,21,18,20)	0.97	394.44	89.01
40	(502,439,1000,759)	(41,21,18,20)	1.00	392.26	96.77
50	(481,418,1000,738)	(41,21,18,20)	1.04	393.68	102.78
60	(459,396,1000,716)	(41,21,18,20)	1.07	389.65	112.39
70	(438,374,1000,694)	(41,21,18,20)	1.11	388.73	120.73
80	(416,353,1000,673)	(27.5,2.5,45, -20***)	1.14	203.05	311.98
90	(394,331,1000,651)	(27.5,2.5,45, -20)	1.18	207.09	315.38
100	(373,310,1000,630)	(27.5,2.5,45, -20)	1.22	211.06	318.84

*: Four animal types: s=steers, h=heifers, c=cull cows, r=replacement heifers.

**: Negative infestation levels represent the addition of clover to a clean fescue pasture

***: Negative replacement heifer rates mean that farmers have to buy replacement heifers to replace cows because of the low calving rate.

Table 4. Net present values and critical infestation level of reestablishment at various infestation levels.

Infestation level (%)	Net present value of reestablishment ($ per acre)	Critical infestation level (%)
-30	$-264.80	
-20	-228.40	
-10	-188.20	
0	-107.30	
10	-43.00	**16.10**
20	27.50	
30	621.30	
40	698.40	
50	758.30	
60	853.90	
70	937.00	
80	2840.70	
90	2874.50	
100	2908.90	

Table 5. Sensitivity analysis for net present values and critical infestation levels of reestablishment.

Infestation level (%)	Net present value ($ per acre)					
	Base Analysis	Changing discount rate		Increasing calving rates by 5%	Changing stand life	
		0.05	0.10		9 years	15 years
-30	$-264.80	$-272.74	$-289.70	$-264.80	$-295.27	$-236.91
-20	-228.40	-240.33	-264.79	-227.33	-266.80	-193.268
-10	-188.20	-204.58	-237.30	-185.14	-235.39	-145.10
0	-107.30	-132.50	-181.89	-96.99	-172.07	-48.02
10	-43.00	-75.26	-137.89	-28.19	-121.79	29.07
20	27.50	-12.46	-89.61	47.80	-66.62	113.66
30	621.30	516.22	316.82	680.84	397.81	825.74
40	698.40	584.94	369.65	765.31	458.18	918.30
50	758.30	638.25	410.63	829.57	505.02	990.11
60	853.90	723.37	476.06	934.74	579.79	1104.75
70	937.00	797.36	532.95	1025.46	644.79	1204.41
80	2840.70	2492.43	1836.05	3038.76	2133.86	3487.52
90	2874.50	2522.53	1859.19	3079.60	2160.30	3528.05
100	2908.90	2553.20	1882.76	3121.37	2187.24	3569.36
Critical infestation level	**16.10%**	**20.2%**	**22.2%**	**13.7%**	**21.4%**	**6.2%**