DENDROCTONUS MICANS (Great Spruce Bark Beetle)

ECONOMIC APPRAISAL OF CONTROL OPTIONS

PURPOSE

1. This appraisal presents a cost-effectiveness analysis of options to control the effects of the Great Spruce Bark Beetle, *or Dendroctonus micans*, on spruce forests in Great Britain[1].

BACKGROUND

2. *D.micans* was first detected in Great Britain near Ludlow, Shropshire in 1982. The known infested area was Scheduled in the Restriction on Movement of Spruce Wood Order 1982 and movement of spruce wood, with bark, out of the designated infested area was prohibited. On completion of the Single Market, and in accordance with EU regulations on the designation of Protected Zones (Council Directive 92/76/EEC), a protected zone comprising the non-infested area of Great Britain and other non-infested parts of the EU was established to prevent the spread of the pest into the spruce forests of England and Scotland and elsewhere. In Great Britain, maintaining controls has involved the designation of three types of area.

a. The *D.micans* Control Area (DMCA) – This is currently the area to the west of the control boundary which runs roughly north-south from Morecambe to Bristol. Controls in this area refer to active intervention to manage the risks of trade-assisted spread of *D.micans* from the DCMA to the rest of the country. The specific predator, *Rhizophagus grandis* has been released at infested sites and there is a requirement that all bark must be removed from any spruce wood before it is transported out of the DMCA.
b. The Peripheral Survey Zone – This is a buffer zone roughly 10 kilometres wide lying within the DMCA to the west of the Protected Zone boundary but within which *D. micans* is not established. Annual surveys of all spruce trees are carried out within this zone to detect and determine rates of natural spread. Sanitation felling and release of *R.grandis* are used to control spread and the boundary of the DMCA has been revised when this has proved necessary.
c. The *D.micans* Protected Zone (DMPZ) – This zone is the remainder of the country and is subject to regular surveys to determine that *D.micans* is still absent. The bulk of British spruce forests lie in this area, in north-east England and Scotland.

[1] Thanks are due to colleagues at the Forestry Commission, particularly Roddie Burgess, Dr. Hugh Evans and Simon Gillam, for providing information and advice on the design, modelling and interpretation of the appraisal.

3. *D.micans* has been detected within the DMPZ, most recently in north Cumbria. This means that under EU regulations it is not permissible to maintain the current control boundary. Therefore, this appraisal is being carried out to assess options for managing the further spread of *D.micans*.

METHODS

4. This appraisal is based on a cost-effectiveness analysis of options for controlling the spread of *D.micans*. The appraisal was carried out as follows:

a. Options for controlling the spread of *D.micans* were identified through discussions with the FC working group overseeing the appraisal.

b. Following the formal consultation exercise, completed in June 2003, key stakeholders in the public and private forest sectors were specifically consulted in October 2003 about the costs of implementing different control options. This consultation also yielded a good deal of qualitative information about the possible effects of the control options on markets for timber and associated products.

c. Previous appraisals of *D.micans* control options were reviewed in order to design an appropriate method for modelling the costs associated with the spread and control of *D.micans*. As a result, some elements of previous models were retained; notably the circular fashion in which *D.micans* is assumed to spread. However, the costings for different options and timber price levels were altered substantially.

d. A spreadsheet model was constructed in order to estimate net present values and annual equivalent values for the options for controlling *D.micans*. Precise costings and control options were adjusted in consultation with the working group and relevant staff in Forest Enterprise.

THE OPTIONS

5. Two main options were identified. However, particularly within Option 2, there are a number of sub-options for taking forward any control strategies.

- *Option 1* – Rescind the boundary, using biological control to reduce the damage costs to spruce of *D.micans*. This might be equated to a “do minimum” option, although it would require an organised programme of rearing and release of the natural predator, *R.grandis*.

- *Option 2* – Establish a new boundary to take account of the spread of *D.micans* into the Lake District, Kent and Devon, using biological control at all new sites of infestation. This boundary would run south from the Solway Firth (to the east of Cumbria) and then east to the Humber estuary. It would be 477 kilometres long. It is assumed that the boundary would be removed in either 3, 5, 10 or 20 years due to *D.micans* spreading northwards into the DMPZ. Following removal of the boundary, biological controls would continue and damage costs from the spread of *D.micans* would accrue in the same way as in Option 1.

THE MODEL

6. Appraisals of options for controlling *D. micans* have been carried out on several occasions since 1992. These appraisals have been based on the premise that the controls are worth having when the costs of controls in a year are less than the expected cost of a new infestation in terms of timber loss. This is expressed in the formula below.

$$C_{cx} < p(N_x)(CN_x)$$

where:

C_{cx} = control costs in year x

$p(N_x)$ = probability of an outbreak in year x

CN_x = costs of an outbreak in year x

7. The expected cost of a new infestation is the cost of an infestation multiplied by the probability of it occurring. The model therefore relies on the probability of an outbreak, the cost once it occurs and the costs of control. As in earlier appraisals, the model assumes that up to five infestations are possible, and applies probabilities to the likelihood of having between one and five infestations. The optimistic scenario assumes a higher probability that there will only be one infestation, and the pessimistic scenario assumes a higher probability that there will be five infestations. The model assumes that one extra outbreak occurs in each of the first five years. Experience in England shows that there have been three outbreaks (in Ashford [Kent], the Lake District and South Molton [Devon]) since 1993 when the control boundary was last amended.

8. The appraisals carried out since 1992 have not used identical techniques to model the spread and damage costs of *D.micans* infestations. The current appraisal has modelled the spread of *D.micans* in the same way as the in the 1998 appraisal, but has used three different approaches for incorporating damage costs into the model (in order to provide some triangulation and to give greater confidence in the final results). A detailed description of these formulations is given in Appendix A. The current appraisal also incorporates a more extensive range of costs of maintaining a boundary, and assumes that any boundary will be temporary (for up to 20 years).

9. The timescale for the appraisal is 50 years. Boundary control costs are applied over the period for which a boundary is assumed to be present (see Table 1). 10 and 5 year timescales are also used in order to test the sensitivity of the results to the length of the appraisal period.

COSTS

10. Two categories of costs are examined in this appraisal:

a. damage costs of *D.micans* infestations due to loss of timber yield; and,
b. costs of control measures to prevent the spread of D.micans.

Damage Costs of Infestation

11. The cost of an infestation depends on the rate of spread of *D. micans* and the subsequent cost in terms of timber loss.

12. The following assumptions have been made in estimating the damage costs of an infestation:

- The spread of *D.micans* is assumed to take place in a circular manner and at a steady rate (see Appendix A for further discussion). The beetle is assumed to spread at a rate of 5km in year 1, declining thereafter by 5% each year until it becomes constant at 2km per year.
- Prior to the first releases of *R.grandis* in 1984, the average mortality rate in a timber stand infested with *D.micans* has been estimated to be about 2% (Evans *et al*. 1985), although some timber in affected stands can be extracted for timber. However, economic losses are now assumed to be between 0.25% and 1% of the total area infested. This accords with analysis of damage and mortality levels in the absence of active management (O'Neill and Evans 1999) but assumes that *R.grandis* is present in infested areas.
- Costs represent the loss from yield class 12 Sitka spruce at optimum felling age (with thinning) with 417 trees per hectare remaining. These parameters are based on Forestry Commission Yield Class Models.
- The model enables any chosen price level or discount rate to be used although, in accordance with guidance in the Treasury Green Book (HM Treasury 2003), 3.5% is the preferred discount rate[2]. Current timber prices (i.e. March 2003) are used as the default price level.

D.micans Control Costs

13. Control costs comprise the costs of biological controls and of the regulatory requirements of maintaining a control boundary. Where necessary, a multiplier of 1.7 has been used[3] to aggregate costs incurred by the public sector (Forest Enterprise) to the costs incurred by the public and private sectors. Values for the following control costs have been estimated.

- *R. grandis propagation and release* – Based on estimates provided by Forest Research, these costs are assumed to be £25,000 per year. They apply equally to both options and, therefore, have not been included in the appraisal. Adequate stocks of *R.grandis* are needed to allow introduction of the predator at infested sites.

[2] 6% was the recommended discount rate in the previous Green Book (prior to 2003).
[3] Forest Enterprise accounts for approximately 60% of current production of timber .

- *Survey costs* – The control boundary consists of a 10-kilometre buffer zone which is surveyed in a systematic fashion in order to identify outbreaks of the pest.
- *Vehicle cleaning* – All vehicles carrying timber harvested in an infested zone have to be cleaned if crossing the control boundary into the protected zone. Vehicles returning to the protected zone also have to be cleaned. The level of effort required for effective cleaning depends in part on the type of vehicle, but a 'brush-down' taking about 15 minutes is considered adequate. This is in addition to the more general cleaning carried out before vehicles access the public highway. Based on estimates supplied by Forest Enterprise in England and Scotland and by industry operators, cleaning costs are assumed to be £10 per vehicle.
- *De-barking* – All timber passing from an infested zone to a protected zone requires de-barking. Estimates supplied by Forest Enterprise in England indicate that de-barking costs £5/m^3. It is possible some revenue is generated by selling bark, but this has not been accounted for.
- *Reduced haulage logistics* – Consultations with haulage operators concluded that additional vehicle cleaning time (see above) will reduce the number of trips that drivers can make in a day. The appraisal assumes a consequent 5% increase in haulage costs.
- *Policing lorry movements* – Policing of lorry movements across the control boundary has not been used following the advent of citizen band radio and, more recently, mobile phones which has made effective detection of infringements increasingly difficult. In addition to being only partially successful, policing measures would also be very expensive to administer.

The assumptions used in the costings are summarised in Table 1.

Table 1 – Costs of maintaining a boundary to control the spread of *D.micans*

Type of cost	Assumptions	Annual cost
Vehicle cleaning	• £10 per load, • 16,240 Forest Enterprise England and Scotland loads, assumed to be 60% of the total	£270, 667
De-barking	• £5/m^3, • 51630 m^3 of FE England movements, assumed to be 60% of the total • (no de-barking for timber originating in Scotland) • no provision made for revenues from selling bark	£430, 250
Reduced haulage logistics	• based on average haulage cost of £8/t, with 5% increase in haulage costs	£200, 000
Policing	• not costed, as this is considered to have limited effectiveness and, therefore, unworkable in practice	

Other costs

14. There are further costs associated with the options identified in this appraisal. However, these have not been included in the quantitative analysis for one or more of the following reasons:

- they do not represent additional economic resource costs but rather are transfers[4] between individuals or firms in the supply chain (i.e. a loss to one results in a corresponding gain to another);
- they are 'sunk' costs and, therefore, cannot be redeemed – for example, where timber mills have already invested in equipment to process infested timber.
- they are impossible to quantify with a reasonable degree of accuracy or a proportionate degree of effort, either because they cannot be objectively identified or because there is inadequate data to assess their extent.

This economic appraisal assesses resource costs at a Great Britain level. This is in accordance with Treasury guidance. It does not specify the costs (or benefits) to specific individuals, organisations, countries or regions.

RESULTS

Quantitative analysis

15. Results of the appraisal are presented on a discounted basis in terms of Net Present Values (NPVs) using a 3.5% discount rate. The period for the appraisal is 50 years, although results were also calculated for shorter appraisal periods (see paragraph 9). Annual Equivalent Values (AEVs) are also presented. AEVs are uniform annual expenditures that, when summed and discounted over the period of an option, are equal to the NPV of an option. The NPVs and AEVs represent costs although are not preceded in Table 1 with minus signs. The option with the lowest NPV and AEV should, therefore, be the option that is adopted.

16. The spreadsheets that were used to calculate the results are shown in the accompanying file. Levels of control boundary costs, timber prices and discount rates can be adjusted on the worksheet entitled 'Results', in order to carry out sensitivity analysis.

17. Table 1 compares the NPVs and AEVs for Options 1 and 2. Option 1 shows results according to different probabilities (i.e. normal, optimistic, pessimistic) of the rate of spread of *D.micans* (see Appendix A for fuller explanation) and for different rates of spruce mortality (0.25% to 1%) resulting from infestations. Option 2 shows results according to whether a boundary is established from years 0-2, 0-5 and 0-10, and also shows results according to different infestation probabilities.

[4] In economic analysis, resource costs are payments for goods and services whereas transfers are payments for which no good or service is received in return.

18. Table 1 shows that a control boundary is not cost-effective, especially at lower rates of mortality. It is assumed that, if the boundary is removed, *D.micans* spreads at the same rate as under Option 1. Therefore, the establishment of a boundary serves to delay the natural spread of the pest while incurring substantial control costs (i.e. lorry cleaning, de-barking, reduced haulage logistics). Therefore, the result that the boundary is not cost-effective conforms to expectations.

19. The rate of mortality is clearly important to the outcome. This is because, at higher rates of mortality, damage costs represent a greater proportion of total costs; therefore, boundary control costs become less influential to the results. In the same way, damage costs also assume a higher proportion of total costs under the pessimistic assumptions of *D.micans* infestations.

Table 1 Options for managing the spread of *D.micans (£)*

OPTION 1 – RESCIND THE BOUNDARY

Option 1: 5 km spread, decreasing at 5% per annum

		0.25 % loss	0.5% loss	0.75% loss	1% loss
Normal	NPV	2,667,009	5,334,018	8,001,028	10,668,037
	AEC	113,704	227,409	341,113	454,818
Optimistic	NPV	2,113,381	4,226,762	6,340,143	8,453,524
	AEC	90,101	180,203	270,304	360,405
Pessimistic	NPV	3,193,503	6,387,005	9,580,508	12,774,010
	AEC	136,151	272,302	408,453	544,603

OPTION 2a - ESTABLISH NEW BOUNDARY (control costs from years 0-2)

Control costs:

NPV	2,723,514
AEC	116,113

Timber loss: 5 km spread, decreasing at 5% per annum

		0.25 % loss	0.5% loss	0.75% loss	1% loss
Normal	NPV	2,255,618	4,511,235	6,766,853	9,022,470
	AEC	96,165	192,331	288,496	384,661
Optimistic	NPV	1,798,467	3,596,935	5,395,402	7,193,869
	AEC	76,675	153,351	230,026	306,701
Pessimistic	NPV	2,689,401	5,378,803	8,068,204	10,757,606
	AEC	114,659	229,318	343,977	458,637
Total cost:					
Normal	NPV	4,979,131	7,234,749	9,490,366	11,745,984
	AEC	212,279	308,444	404,610	500,775
Optimistic	NPV	4,521,981	6,320,448	8,118,916	9,917,383
	AEC	192,789	269,464	346,139	422,815
Pessimistic	NPV	5,412,915	8,102,316	10,791,718	13,481,119
	AEC	230,773	345,432	460,091	574,750

OPTION 2b - ESTABLISH NEW BOUNDARY (control costs for years 0-5)					
Control costs:					
NPV	5,167,060				
AEC	220,291				
Timber loss:	**5 km spread, decreasing at 5% per annum**				
		0.25 % loss	0.5% loss	0.75% loss	1% loss
Normal	NPV	1,913,033	3,826,065	5,739,098	7,652,131
	AEC	81,560	163,119	244,679	326,239
Optimistic	NPV	1,538,822	3,077,645	4,616,467	6,155,289
	AEC	65,606	131,211	196,817	262,423
Pessimistic	NPV	2,267,220	4,534,440	6,801,661	9,068,881
	AEC	96,660	193,320	289,980	386,640
Total cost:					
Normal	NPV	7,080,093	8,993,126	10,906,158	12,819,191
	AEC	301,851	383,410	464,970	546,530
Optimistic	NPV	6,705,883	8,244,705	9,783,527	11,322,349
	AEC	285,897	351,502	417,108	482,714
Pessimistic	NPV	7,434,280	9,701,501	11,968,721	14,235,941
	AEC	316,951	413,611	510,271	606,931

OPTION 2c - ESTABLISH NEW BOUNDARY (control costs for years 0-10)					
Control costs:					
NPV	8,718,876				
AEC	371,718				
Timber loss:	**5 km spread, decreasing at 5% per annum**				
		0.25 % loss	0.5% loss	0.75% loss	1% loss
Normal	NPV	1,446,011	2,892,022	4,338,033	5,784,044
	AEC	61,649	123,298	184,946	246,595
Optimistic	NPV	1,184,049	2,368,098	3,552,148	4,736,197
	AEC	50,480	100,961	151,441	201,922
Pessimistic	NPV	1,692,690	3,385,379	5,078,069	6,770,759
	AEC	72,166	144,331	216,497	288,663
Total cost:					
Normal	NPV	10,164,887	11,610,898	13,056,909	14,502,920
	AEC	433,367	495,016	556,664	618,313
Optimistic	NPV	9,902,926	11,086,975	12,271,024	13,455,073
	AEC	422,198	472,679	523,159	573,640
Pessimistic	NPV	10,411,566	12,104,256	13,796,946	15,489,635
	AEC	443,884	516,049	588,215	660,381

Sensitivity analysis

20. Both Options 1 and 2 already have a substantial degree of sensitivity analysis within them, in relation to timber mortality, the probabilities of different incidences of infestations and period over which a boundary is maintained. However, it is appropriate to examine the sensitivity of the results to changes in other key parameters; notably, control costs, timber prices and the length of the appraisal period.

21. Substantial reductions in the levels of control costs are required to make significant changes to the results. An 50% reduction in control costs (which would result if de-barking costs were ignored) renders the establishment of a boundary cost effective, but only under normal and pessimistic likelihoods of infestations at 1% mortality, or a pessimistic likelihood at 0.75% mortality. In all other cases at this level of costs, the boundary is not cost effective. A 75% reduction in costs makes the boundary cost-effective at 1% and 0.75% mortality, and at 0.5% mortality under normal and pessimistic likelihoods of infestation. A 95% reduction in costs makes the boundary cost-effective at all mortality levels.

22. Current timber prices are at historically low levels. It is beyond the scope of this appraisal to assess whether prices will rise or fall in the period of this appraisal, but it is important to consider the effects of further price changes. A substantial percentage price increase would be required to change the outcome of the appraisal. This is because price rises increase the damage costs in both Options 1 and 2. If prices were to increase by 75%, boundary controls would be cost-effective at a 1% mortality rate if normal or pessimistic likelihoods of infestation are assumed. The results are not very sensitive to higher price increases. A 150% increase in prices would render the boundary cost-effective at 1% mortality, and cost-effective at 0.75% mortality if normal or pessimistic likelihoods of infestation are assumed. Even if prices were to increase by 200%, the boundary would remain unviable at 0.5% and 0.25% rates of mortality.

23. Clearly, major changes in costs or prices are necessary to change the results of the appraisal. In practice, simultaneous changes in both of these parameters may be envisaged. The results are moderately sensitive to such changes. For example, a 30% increase in prices and a 30% reduction in costs would render the boundary cost-effective at 1% mortality if normal or pessimistic likelihoods of infestation are assumed. A 50% increase in prices and 50% reduction in costs would render the boundary fully cost-effective at 1% mortality and cost-effective at 0.75% mortality if normal or pessimistic likelihoods of infestation are assumed. A 75% increase in prices and 75% reduction in costs would render the boundary cost-effective if mortality is 0.5% or greater.

24. The current appraisal uses a 3.5% discount rate, following Treasury guidance for government departments. Using a 6% rate (as under previous Treasury) guidance has the effect of reducing the net present costs of both options, and accentuates the difference in values between Option 1 and 2. This is because the damage costs occurring further into the future are discounted substantially more than the short-term boundary control costs.

25. A further option is to alter the period over which the appraisal runs, as long as this period exceeds the period during which a boundary is maintained. Running the appraisal over a 5 or 10 year period (rather than 50 years) substantially reduces the relative cost effectiveness of maintaining a boundary. This is because high levels of control costs would accrue in the

this period whereas damage costs from the spread of *D.micans* take longer to accumulate. Running the appraisal over a longer period allows greater account to be taken of damage costs which become substantial as the pest spreads. However, the fact remains that Option 2 only serves to delay the onset of these damage costs.

Qualitative results

26. The consultation with key stakeholders generated a range of comments about the possible effects of different options for controlling *D.micans* on markets for timber and associated products. Some of these comments related to ways in which individual sub-sectors and/or businesses might be affected. For example, it was felt that the establishment of the control boundary across a marketing zone would restrict the free movement of timber and co-products such as bark. Many of these costs have been incorporated in the models used in this appraisal. However, there was insufficient data to quantify the effects on individual sub-sectors or businesses.

27. Care should also be taken in examining the effects of *D.micans* control options on timber markets to ensure that all effects relate to economic resource costs rather than transfers. This economic appraisal is concerned with the former in order to assess the net effects to the GB economy.

28. An example of a transfer (as opposed to a resource cost) is where price differentials develop between timber supplied from infested and protected areas. Such timber can only be processed at certain mills that have treatment facilities that reduce the risk of spreading the pest. Therefore competition among sawmills for such timber will be reduced. Economic theory suggests that this will reduce prices. However, changes in raw material prices need to be considered against any effects in the prices of final products. There is only an economic resource cost if final products (following processing) from timber from infested stands sell at a different price from final products from timber from uninfested stands. Otherwise, lower prices for timber from infested stands just represent a transfer within the supply chain from growers to producers (in the form of lower prices). Therefore, these market effects are not included in the costs that assessed in this appraisal.

Risks and uncertainties

29. As in any appraisal, there are risks and uncertainties that the actual outcomes will vary from the predicted outcomes. The following risks and uncertainties have been identified:

a. Research has indicated that the natural predator, *R.grandis*, is effective in controlling the mortality resulting from *D.micans* to 1% or less. However, there is a risk that *D.micans* may be transported on a lorry to a new site unaccompanied by *R.grandis*. Where *R.grandis* is not present, mortality associated with *D.micans* may be as high as 10% until it is detected and *R. grandis* artificially introduced. Forest Research has developed a procedure for early identification of new outbreaks of *D.micans* so that such losses may be minimised[5]. Nevertheless, such procedures may be more difficult to implement in the large and denser spruce forests that are found in north-east England and Scotland.

b. Experience in Wales and England has shown that D.micans has spread beyond previous control boundaries. Given that policing of the boundary is not considered realistic (see paragraph 13), it is inevitable that the substantial costs associated with the boundary proposed under Option 2 will fail to prevent damage costs to the spruce forests of northern Britain. In practical terms, a control boundary can only be regarded as a device to delay mechanical spread although, in combination with a buffer zone in which active management of new infestations (selective tree felling and introduction of *R.grandis*) is pursued, it can be expected to have a significant limiting effect on natural spread.

c. Many of those consulted identified substantial costs for maintaining a control boundary and these have been included in this appraisal. There is a risk that these costs may be over-estimated, particularly where operators fail to fully observe recommended control actions or where tasks prove less onerous than foreseen.

d. The consultation also revealed that removal of the control boundary under Option 1 would threaten markets for Scottish timber in Ireland. However, since the publication of the Consultation Paper, the option to establish a new control boundary around the relevant timber-producing areas in West Scotland has been exercised and a pest-free area for *D.micans*, as well as *Ips sexdentatus* and *I.cembrae* (both pests absent from the protected zone of Ireland and Northern Ireland), has been established. This exercise has, therefore, not been costed as part of Option 1. The current appraisal has also not costed the effects of the potential loss of timber markets to Ireland which would arise in the event that any of three listed pests was found in the West Scotland area. Further work would be required to investigate the net effects of such a loss on GB timber markets.

30. The level of each of these risks is illustrated in Table 2.

Table 2 Risks and uncertainties

Type of risk	Level of risk	
	Option 1	Option 2
Higher mortality rates due to absence of *R.grandis*	High	Low/medium
Failure of boundary to constrain *D.micans*	-	Low/medium
Over-estimation of control boundary costs	-	High
Incidence of more than 5 outbreaks	Low/medium	Low
Loss of Irish markets for Scottish timber	Low	Low

[5] A new strategy using a chemical analogue of the specific attractant used by *R. grandis* to find *D. micans* is being tested. The principle is to release the predator in forests where *D. micans* is assumed to be absent and to set up traps with the specific attractant one year later. If *R. grandis* are captured then *D. micans* is present in the forest because the predator would not be able to survive without breeding on the bark beetle. This strategy has the advantage of being more efficient than visual survey and also contributes to very early establishment of the predator in the newly infested location.

CONCLUSIONS

31. This appraisal finds that establishing and maintaining a new boundary to control the spread of *D.micans* is not cost effective. Some broad assumptions about boundary costs are used, although substantial changes are needed to costs (and to timber prices) to cause a major change in the outcome of the appraisal.

32. The results of this appraisal differ substantially from earlier appraisals of options for managing *D.micans*. This may be surprising at first glance because the major bulk of the spruce resource remains outside the current and revised boundaries and, therefore, potential damage costs from the further spread of *D.micans* remain substantial. However, there are a number of reasons why the results of the current appraisal differ from earlier analyses:

- following responses to the consultation with key stakeholders, a greater range and magnitude of costs have been applied under the current appraisal to control measures required to maintain a boundary;
- the control boundary is assumed to last only in the short to medium term and is, therefore, considered only to delay the damage costs that would be incurred if there was no boundary; and,
- current timber price levels (which are substantially lower than several years ago) have been used in the current appraisal, thereby reducing the damage costs from *D.micans* infestations.

Pat Snowdon
Corporate and Forestry Support
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APPENDIX A

Modelling of D.micans spread

The model of the spread of *D.micans* is based wholly on mathematical formulae (as in earlier appraisals) in which it assumed that *D.micans* spreads in a circular fashion and that geographical distribution of spruce is uniform. In reality, the geographical shape of Great Britain precludes the possibility of ongoing circular spread (as some parts of the circle reach coastlines) and spruce tends to be concentrated in certain areas. There is potential in future to model the spread of *D.micans* using GIS software, but this approach has not been possible within the time and resource constraints of this appraisal.

Modelling of damage costs of D.micans spread

A 50-year period (equivalent to one rotation) is used in the model. The modelling assumes that *D.micans* spreads through a mixed-aged areas of spruce. It also assumes that 6.4% of the protected area is covered in spruce (based on Forestry Commission tree cover data[6]). Therefore, damage costs are reduced accordingly.

Three approaches were tested in this appraisal to model the damage costs that result from the spread of *D.micans*.

Method 1
Method 1 applies annual equivalent values (AEVs) for damage costs to the function that models the spread of *D.micans*. AEVs are derived from the per tonne timber price for the appropriate size category multiplied by the volume of timber per $km/^2$. Values are adjusted for different mortality rates.

Given that AEVs vary with discount rates, discounting the cumulative damage costs back to the present results in double-discounting. This is apparent when varying the discount rates, because a much larger change in NPV is achieved than would be expected. Therefore, a variation on this method was also used, whereby the results are run without discounting the cumulative damage costs.

Method 2
Method 2 applies the damage costs as annual average values which do not vary with the discount rate. However, the NPVs are still converted to AEVs in order to provide annual cost comparisons in the results. The annual average value is calculated by multiplying the per tonne timber price for the appropriate size category, first, by the volume of timber per $km/^2$ and, second, by a fiftieth (because each year only one fiftieth of the crop is harvested).

A different approach to method 1 is used to calculate the annual damage cost values. As *D.micans* infests an area, the extent of the damage cost will depend on the age of the tree; for example, a tree aged 49 will only have a

[6] Forestry Commission (2003) *Forestry Statistics 2003*, Edinburgh: Forestry Commission

damage cost for one year's growth applied, whereas a tree aged 10 years will have damage costs for 40 years' worth of growth applied.

Method 3 - combined approach

The method that was used to generate the results in this report combined elements of Methods 1 and 2 (i.e. the Method 1 approach for modelling the spread of *D.micans* and the Method 2 approach for calculating annual average values).