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Nectria flute canker delimiting surveys

L. S. Bulman

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EXECUTIVE SUMMARY

Objective

The aim of this work was to determine the rate of spread of *Neonectria fuckeliana* and to delimit its distribution.

Key Results

1. Results from routine forest health surveillance and delimiting surveys indicate that *N. fuckeliana* spread throughout the lower South Island first, and then northwards.
2. The spread of *N. fuckeliana* appears to have slowed in Canterbury.
3. By the end of 2008, the fungus spread as far north as Banks Peninsula.
4. The fungus has not been found in Nelson, Westland, or anywhere in the North Island where surveys have been carried out.
5. There is an apparent contradiction between distribution and spread of the fungus as determined by these surveys and the finding that the fungus is present in trees pruned in the 1980s. More work needs to be done to explain this contradiction.

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INTRODUCTION

At a meeting of the Nectria Focus Group held at Mosgiel in December 2003, there was discussion on the merits of conducting a delimiting survey to determine the spread and northernmost extent of *Neonectria fuckeliana* and the disease it is associated with, Nectria flute canker. The survey methods were proposed, developed, discussed, and refined from early to mid 2004. It was decided to proceed with a less intensive national survey before undertaking the delimiting survey. There were several reasons for doing so.

1. If the fungus was found in Nelson or in the central North Island the objectives of the delimiting survey would have to be re-evaluated.
2. Carrying out the smaller national survey would allow problems to be identified and improvements to be incorporated into the delimiting survey.
3. Planning the delimiting was taking much longer than anticipated because of the need to identify owners and ask permission to survey and sample.

Preparatory work identifying sites to be inspected, contacting owners, obtaining permission, and producing survey maps and material was undertaken from mid 2004 to mid 2005. The national survey was undertaken from October to December 2004. In October 2005 the delimiting survey started. Both surveys involved visual inspection and sample collection from trees that displayed suspicious symptoms. In addition, routine forest health surveillance was undertaken as part of the NZFOA surveillance scheme.

Since 2005, the surveys have been intensified and redone in areas where the disease was newly discovered, and expanded as the disease was found further north.

Surveys were funded by the Forest Biosecurity Research Council, Forest Industry Development Agenda, and Scion's FRST Biosecurity programme.

METHODS

Delimiting Survey objectives

The delimiting survey had two objectives.

1. Determine the extent and distribution of the disease and its causal agent

2. Determine disease incidence throughout the survey zone

The rate of spread of a pest or disease can be estimated from two functions, (a) the distance of isolated colonies from the main population, and (b) population numbers in a colony as a function of colony age. The two objectives above were formulated to answer (a) and (b).

Objective 1 aimed to delimit the boundaries of the disease by determining its distribution within the survey zone. After this has been done, the probability of whether the outer points are the actual boundaries of disease spread or whether the disease is present outside the survey zone can be estimated.

Figure 1 from Sharov & Liebhold (1998) shows this graphically. Using it in context, the infested zone was considered to be Otago/Southland, the transition zone South Canterbury, and the uninfested zone was assumed to be Canterbury. The probability of disease establishment, $b(x)$, decreases with increasing distance from the front of the infested zone.

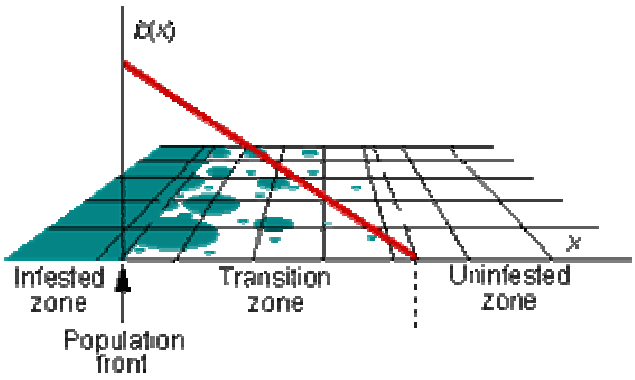


Figure 1 – Three zones of an expanding population front

Objective 2 aimed to determine disease incidence within plantations throughout the survey zone. Disease incidence data will provide information that will enhance the demarcation of the infested zone, transition zone, and the uninfested zone. As disease spreads its incidence reduces because newly established infection centres need time for population numbers to build up. Therefore the number of diseased individuals increases with time and thus the time that the disease has been present in an area can be estimated.

Survey zone

In April 2004, the survey zone covered the wood supply regions of Central Otago, Queenstown Lakes, Waitaki, Waimate, Timaru and MacKenzie (Fig. 2). The intention was to survey those regions, estimate the extent of the transition zone, and then make recommendations on whether the survey zone should be extended or not.

On 17 May 2004 it was confirmed that *Neonectria fuckeliana* was present in a forest near Waimate and at Geraldine Forest. Samples were collected as part of a routine forest health inspection. The survey zone was extended approximately 100 km northwards as a result of the finding (see Figure 2 showing expanded zone).

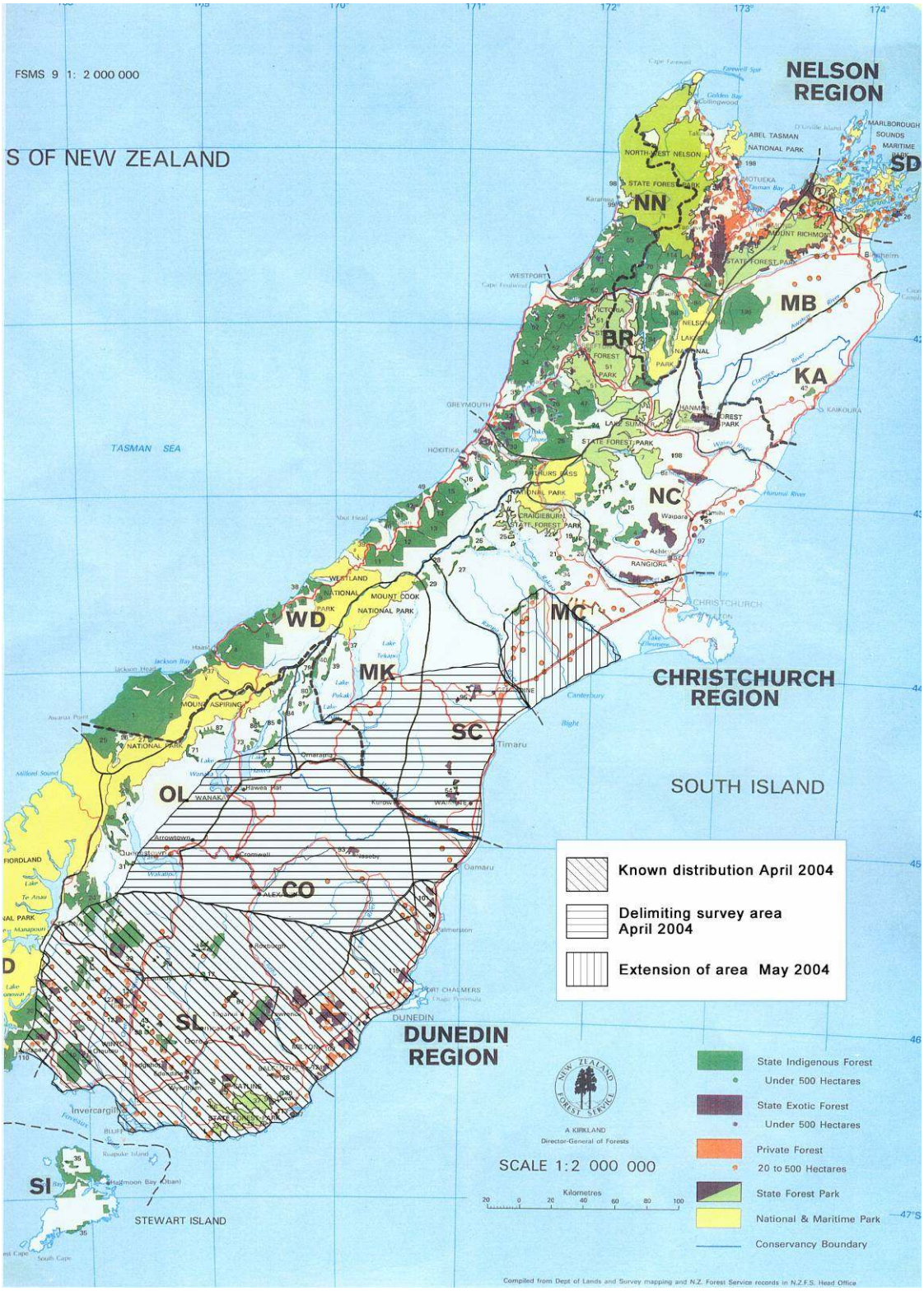


Figure 2 – South Island showing the infested zone, the initial delimiting survey zone, and the revised survey zone.

Forest selection and access

The aim was to sample as many forests and plantations as possible in order to increase the probability of detecting the fungus if it was present. This is particularly relevant for the regions inspected because large areas of contiguous forest were not present. Plantation pine forests

were often small, isolated, and widespread. It was recognised that approval to survey and sample was needed from forest companies and individual owners before the survey could start.

Identifying the large forests was not difficult. Most were surveyed as part of the NZFOA forest health surveillance scheme. The major forests in the Timaru, Waimate, MacKenzie, Waitaki, Central Otago, and Otago Lakes districts were identified. Table 1 shows the area of *Pinus radiata* plantings in these regions. South Westland was excluded from the survey because there is a natural barrier that will limit the spread of the disease, and there is little *P. radiata* present in that region.

Table 1 Area of *P. radiata* by wood supply region and age-class as at 1 April 2002 (1-20 years)*

Territorial authority	1-5	6-10	11-15	16-20	Total (6-20 years)
Mackenzie District	269	2817	313	104	3234
Timaru District	749	3669	1352	778	5799
Waimate District	3968	4203	986	1467	6656
Waitaki District	3586	3254	1329	1420	6003
Queenstown-Lakes District	1	55	28	12	95
Central Otago District	37	567	183	491	1241

* Source: NFED 2002. MAF, Wellington, 2003

The major forests selected for survey in those regions were Geraldine (4,300 ha), Naseby (2,200 ha), and Waimate (2,900 ha). Herbert (3,900 ha) was surveyed because it was in the Northern part of the Dunedin wood supply region. A search of the Forest Health database revealed a further 46 locations where inspections of *Pinus radiata* had been carried out. The major growers were the District Councils of Waimate (1,200 ha in 5 forests), MacKenzie (800 ha), and Timaru (unknown area).

The difficulty lay in obtaining information on where the smaller plantations and woodlots were located. After evaluating various options it was decided to use the Land Cover Database (LCDB2) information to obtain forest locations. The information was extracted and locations mapped and put into shapefiles. However, the LCDB2 does not provide age class or physical address. AgriQuality were contracted to link the LCDB2 with their Agribase database to provide information on owner and address, restricted to *Pinus radiata* aged between 7 and 15 years old. That information was extracted, plantations were selected to provide a wide distribution of locations throughout the delimiting survey zone, and letters were sent to plantation owners requesting permission to survey and sample their plantations for the presence of the disease and fungus. After permission was received a total of 300 plantations had been selected for inspection.

Survey method and sampling

The percentage of trees with fluting present was assessed in 5% steps. The assessor recorded the date, the location coordinates using a GPS, whether fruit bodies were present or absent, age and silviculture, and any comments relevant to the survey.

It was necessary to confirm the presence of the fungus by sampling and laboratory analysis. Where fluting is seen, five fluted trees were sampled. This number was based on work done previously that showed of the trees where the fungus was known to be present, 60% were confirmed positive by taking one sample. The increment core sample was taken just above the fluted stub. The core was deep enough to obtain sapwood from deeper than the branch trace, i.e. about 100 mm. The equipment was sterilised between sampling individual trees by placing it in a screwtop jar of methylated spirits, flaming, and then allowing to cool before reusing. When resin built up it was rubbed off with an alcohol-soaked rag. Individual samples were packaged

separately to avoid cross-contamination. For example, each core was wrapped in a paper towel or placed in a separate bag or envelope. Each core was individually labelled. They were kept in a fridge (or chilly bin) until a package was prepared if it was not possible to post immediately. Whenever fruiting bodies were seen they were collected (still attached to the bark) and sent to Scion for formal identification.

From February 2008 onwards, as a result of research that showed *N. fuckeliana* may be present in asymptomatic trees, procedures were changed. Surveyors were required to take samples from all stands surveyed, whether fluting was present or not. A minimum of three, but usually five, samples were taken from each stand.

A total of 899 stands were inspected, of which 533 were not sampled. A total of 1021 samples were taken from the remaining 366 stands.

National survey

A survey in other parts of the South Island and in the central North Island was done in conjunction with this delimiting survey. Nelson, Marlborough, Westland, Canterbury, and Taupo were targeted. Methods were similar to those used in the delimiting survey, except stands were not pre-selected for inspection. Instead, the survey consisted of a drive-through inspection looking specifically for fluting with stops to sample and look for fruiting bodies. This survey was not as intensive as the delimiting survey. The national survey started in October 2004 and was completed in March 2005, with 202 stands inspected.

NZFOA Forest Health Survey

Forest health surveillance in exotic plantation forests began in the mid 1950s. Then, the focus was on monitoring insect populations – in response to outbreaks of sirex wood wasp in the central North Island and looper caterpillar in Canterbury. Since the early 1980s, pest detection has been a major objective of the NZFOA forest health surveillance scheme. Most forests in the southern half of the South Island are visited at least once a year and inspected for the presence of new pests. At the same time, forest health assessments are carried out and the information is stored in the forest health database maintained at Scion. Records of all *Pinus radiata* plantation forest inspections undertaken from 1990 to 2003 were extracted from the database and interrogated for mention of stem canker or other descriptions typical of Nectria flute canker. After 2003, by which time the causal agent of Nectria flute canker had been named, all records of Nectria flute canker or *N. fuckeliana* were extracted and compiled.

Two experienced inspectors carried out 84% of the inspections made over the 1990-2009 period. One inspector was responsible for 55% of the records (mainly in Otago and Southland), the other surveyor provided 29% of the records, mainly from Canterbury.

Survey dates

The delimiting survey started on 26 October 2005 in the Otago Lakes-Central Otago regions. The first series of inspections finished in early December 2005. Dunedin, Otago Lakes, Central Otago, and South Canterbury had been covered. Surveys resumed in South Canterbury and mid Canterbury in late January 2006 and were completed by late February 2006. In late 2006 and mid 2007, surveys were intensified in parts of mid Canterbury and extended into North Canterbury. In late 2007 and early 2008 Marlborough and Nelson were surveyed, followed by South Canterbury and mid Canterbury in April 2008. Lastly, central North Island forests were surveyed in late 2008 (Table 2).

Table 2 – Survey start and finish dates ordered by start date, and number of stands surveyed, by region. The national survey started in 2004 and ended March 2005, the delimiting survey started in October 2005.

Survey type	Region	Start	Finish	Stands surveyed
National	Nelson	14/10/04	18/1/05	36
National	Waikato	20/10/04	1/11/04	6
National	Taupo	1/11/04	18/3/05	31
National	Buller	8/11/04	9/11/04	24
National	Westland	10/11/04	10/11/04	14
National	Marlborough	18/11/04	20/12/04	15
National	North Canterbury	22/11/04	26/11/04	9
National	Mid Canterbury	23/11/04	9/12/04	38
National	South Canterbury	25/11/04	9/12/04	16
National	Bay of Plenty	17/3/05	18/3/05	12
NZFOA Surveillance	Various regions	1/4/05	26/6/05	20
Delimiting	Central Otago	26/10/05	2/12/05	73
Delimiting	Otago Lakes	26/10/05	3/11/05	23
Delimiting	Dunedin	3/11/05	2/12/05	66
Delimiting	South Canterbury	3/12/05	7/12/05	48
Delimiting	South Canterbury	26/1/06	26/2/06	132
Delimiting	Mid Canterbury	29/1/06	21/2/06	46
Delimiting	Marlborough	24/2/06	25/2/06	3
Delimiting	Mid Canterbury	13/11/06	17/11/06	19
Delimiting	Mid Canterbury	26/2/07	5/4/07	64
Delimiting	North Canterbury	1/4/07	1/4/07	16
Delimiting	Mid Canterbury	14/6/07	22/7/07	9
Delimiting	Nelson	13/11/07	18/1/08	53
Delimiting	Marlborough	27/11/07	19/2/08	25
Delimiting	South Canterbury	7/4/08	9/4/08	18
Delimiting	Mid Canterbury	9/4/08	18/4/08	24
Delimiting	Bay of Plenty	30/10/08	18/11/08	27
Delimiting	Taupo	30/10/08	19/11/08	32
	Total			**899**

RESULTS AND DISCUSSION

National Survey

A total of 63 stands were surveyed and sampled in South Canterbury, mid Canterbury and North Canterbury between 22 November and 9 December 2004. Fluting was seen in only three of those stands (5%). A total of 201 stands were inspected of which 24 were sampled. *Neonectria fuckeliana* was not isolated from the 8 trees sampled from the three stands in Canterbury, nor from any of the remaining stands sampled in Nelson/Marlborough (51 stands), West Coast (38) or central North Island (49). *Sphaeropsis sapinea* was isolated from 10 stands; other fungi isolated included *Trichoderma*, *Pestalotiopsis*, *Aureobasidium*, and a white decay fungus.

Fluting incidence was very much lower than that found in the known infected area. Fluting was recorded in just over 13% of the stands surveyed in this study. Results from a regional incidence survey carried out in the Otago/Southland region indicated that over 20% of the 9,180 trees assessed had fluting. Some degree of fluting was recorded in over 90% of 221 randomly placed 20-tree plots.

NZFOA Forest Health Survey

Data collected from forest health surveillance scheme surveys need to be treated with some caution because the primary aim of the survey is to detect new pests. It is not designed to provide precise quantitative data on forest health issues – i.e. surveys are not systematic with regards timing and intensity and there are no specifications on what specific forest health disorders should be assessed.

The data presented in Table 3 should therefore be premised with the understanding that the data are only indicative of the presence or absence of Nectria flute canker, particularly observations made prior to 2000, before the disease was widely recognised. There was no requirement to record stem damage so there is a possibility that stem damage might have been present earlier than the first records suggest. Also, Nectria flute canker might have been wrongly recorded as Diplodia damage. *Neonectria fuckeliana* was isolated from trees growing in Southland that were pruned in the early to mid 1980s (Hopkins *et al*. 2008), suggesting that the fungus was present then.

However, forest health inspections do provide data that are able to be used to show general trends in disease incidence, severity, and distribution.

Records of stem damage prior to 1990 in plantation *P. radiata* growing in Southland or Otago were extremely rare, apart from damage caused by the woolly pine aphid *Pineus laevis*. During the first half of the 1990s a small percentage of inspection records mentioned symptoms that were typical of Nectria flute canker, but only in Southland and Dunedin, but not in other parts of Otago. Few *P. radiata* wood samples were received over that period so it is impossible to determine if *N. fuckeliana* was responsible for the symptoms seen. By the late 1990s, observations were being made in Southland and throughout Otago. In the first half of the 2000s the first records in Canterbury were made, and the percentage of records that mentioned Nectria flute canker symptoms continued to increase in Southland and Otago. Over the last half of this decade it appears that the disease progressed northwards into mid Canterbury.

The Dunedin region had the highest percentage of “positive” records since the mid 1990s, followed by Southland initially, but latterly by Otago Lakes and Central Otago. The disease remains uncommon in Canterbury, based on forest health inspection records.

Table 3 – Number of forest health inspections and percent where Nectria flute canker symptoms or *Neonectria fuckeliana* was recorded

Year	1990-94		1995-1999		2000-04		2005-09	
Region	No.	(%)	No.	(%)	No.	(%)	No.	(%)
North Canterbury	628	0.0	1039	0.0	719	0.0	299	0.0
Mid Canterbury	296	0.0	706	0.0	571	0.0	128	0.8
Mackenzie	1	0.0	1	0.0	1	0.0	2	0.0
South Canterbury	108	0.0	330	0.0	183	2.7	49	2.0
Otago Lakes	12	0.0	50	4.0	57	7.0	15	6.7
Central Otago	35	0.0	130	3.8	99	9.1	54	7.4
Dunedin	1262	0.9	884	8.9	647	13.6	531	16.4
Fiordland	51	0.0	143	2.8	52	0.0	9	0.0
Southland	210	2.9	574	4.4	693	5.3	315	7.3
Total	**2603**	**0.7**	**3857**	**3.0**	**3022**	**4.7**	**1402**	**8.3**

Delimiting Survey

Fluting incidence

The incidence of fluting varied between regions and sampling periods with no trends apparent (Table 4). It should be noted that many different surveyors carried out the surveys and the requirements were to record fluting if it was present. Fluting was common in the North Island and Nelson in 2008, but this was expected because the surveyor was instructed to sample stands that had trees with fluting. Unlike the forest health surveys, the delimiting survey was aimed at determining the presence of *N. fuckeliana* and therefore sampling was biased towards sampling stands with symptoms typical of the disease *N. fuckeliana* causes.

Table 4 – Number of stands inspected and the percentage where fluting was recorded

Period	Oct 2004-Jun 2005		Oct 2005-Feb 2006		Nov 2006-Feb 2008		Apr 2008-Nov 2008	
Region	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Central North Island	49	16.3					59	37.3
Nelson/Marlborough	59	16.9	3	0.0			78	60.3
West Coast	39	10.3						
North Canterbury	15	0.0			16	0.0		
Mid Canterbury	43	7.0	46	30.4	92	45.7	24	12.5
South Canterbury	16	6.3	180	41.7			18	11.1
Otago Lakes			23	47.8				
Central Otago			73	28.8				
Dunedin			66	33.3				
Total	**221**	**11.8**	**391**	**36.6**	**108**	**38.9**	**179**	**41.3**

Distribution and spread of Nectria flute canker

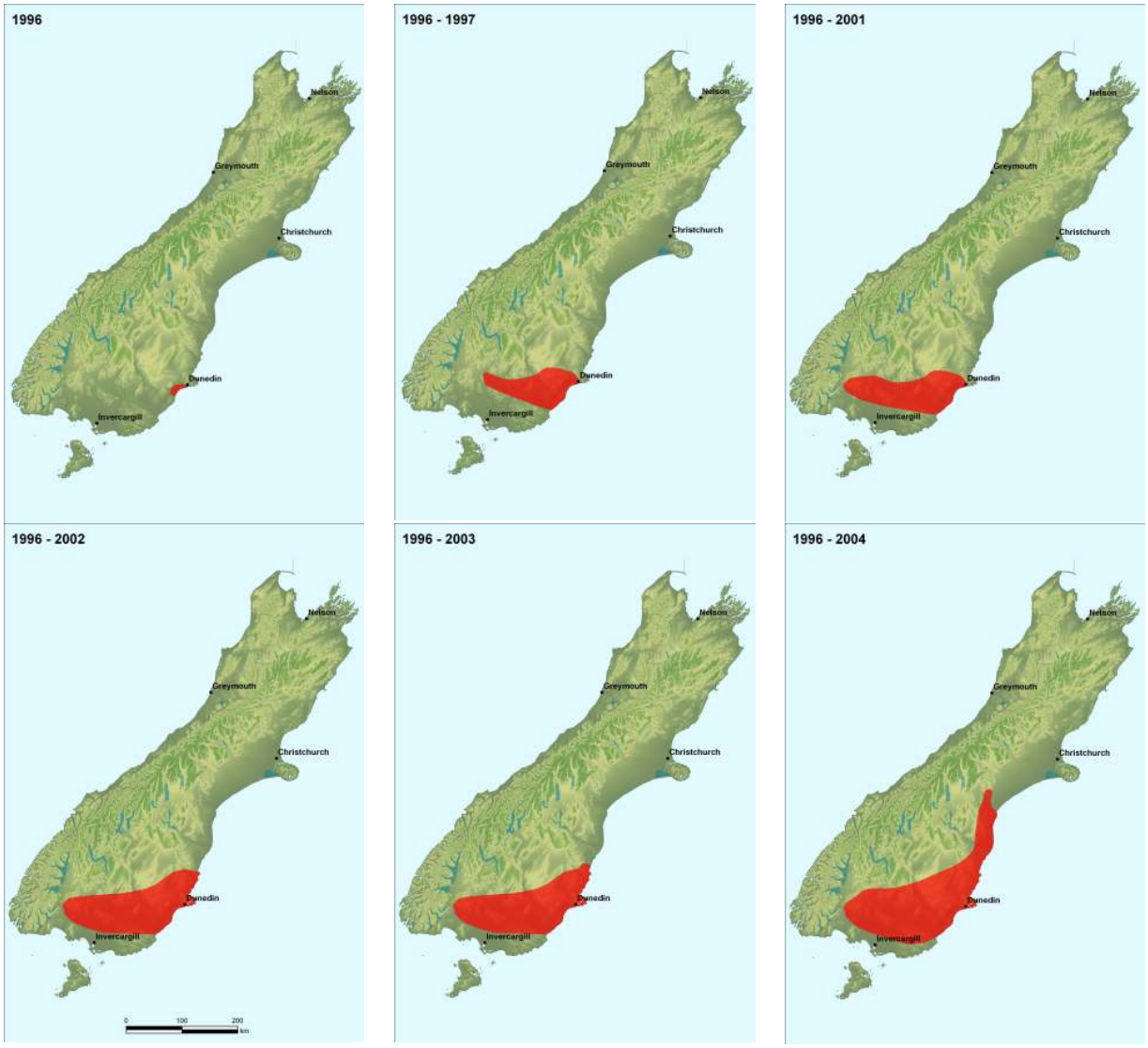
Neonectria fuckeliana was first identified from a sample collected south of Dunedin in 1996. The distribution and spread of the fungus from 1996 to 2004 was determined from samples collected, and observations of the distinctive fruit bodies made, during the routine forest health surveys. The area within which the fungus was confirmed or positive field identifications were made is shown in Figures 3 to 8. They indicate a spread starting from coastal Otago to inland and southwards, and then northwards.

Neonectria fuckeliana was confirmed from Geraldine Forest in South Canterbury in May 2004 during routine forest health surveys. It is possible that the fungus was present in the forest when previous surveys were carried out but it is unlikely that it had been there for a long time. Firstly, Geraldine Forest is regularly surveyed with an average of 24 stands inspected every year during the 1990s and about 10 stands inspected per year in the 2000s. Secondly, the two inspectors were familiar with Nectria flute canker symptoms and were on the lookout for them, and finally, Nectria flute canker and *N. fuckeliana* have been subsequently confirmed in Geraldine Forest and surrounding plantations.

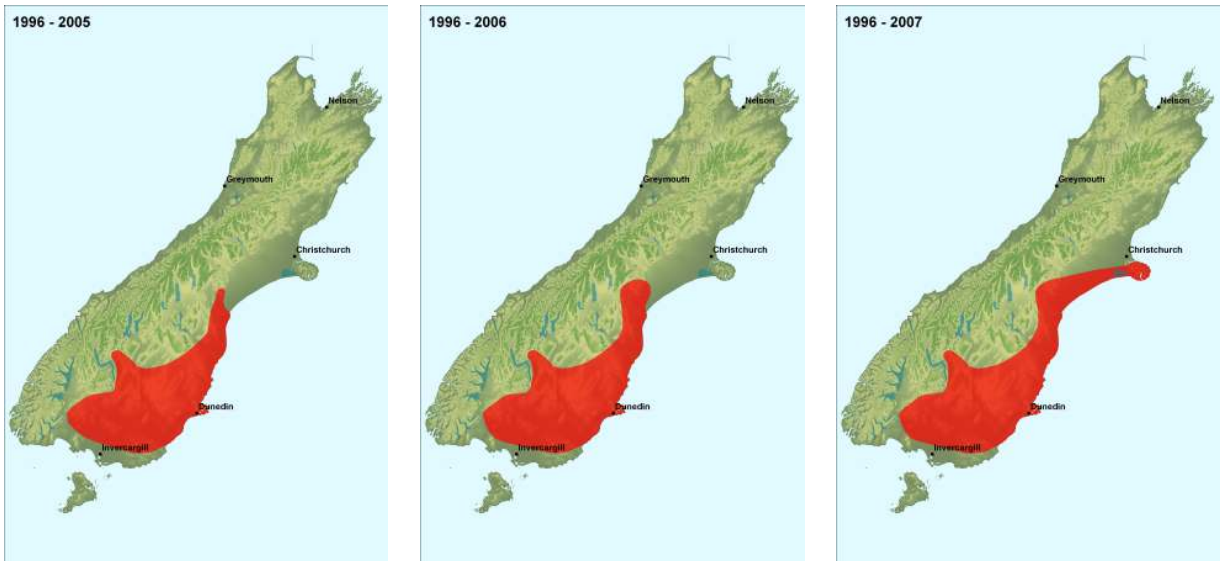
The fungus was not isolated from any of the samples sent in during the national survey in late 2004, and fluting was rare in Canterbury. In February 2007, *N. fuckeliana* was first found in mid Canterbury, on Banks Peninsula.

Figures 9 to 11 show known area from 2004 to 2007. Where years are not shown (1999, 2000, 2006, 2008, 2009) no significant spread occurred. The rate of spread has slowed over the 2004-2009 period is considerably slower than that seen over the earlier period. Crane *et al*. (2009) showed that moisture is needed for spore release and dispersal. It is likely that the dry climate in Canterbury is not conducive for fungal spread and disease development. Experiments were established in early 2009 to monitor the progress of Nectria flute canker on Banks Peninsula

and mid Canterbury (Hopkins & Henley 2009). These trials will provide data on rate of spread of the fungus and disease development at the within-stand and between-stand level.



Figures 3 to 8 – Known distribution of Nectria flute canker from 1996 to 2004.



Figures 9 to 11 – Known distribution of Nectria flute canker from 2005 to 2007.

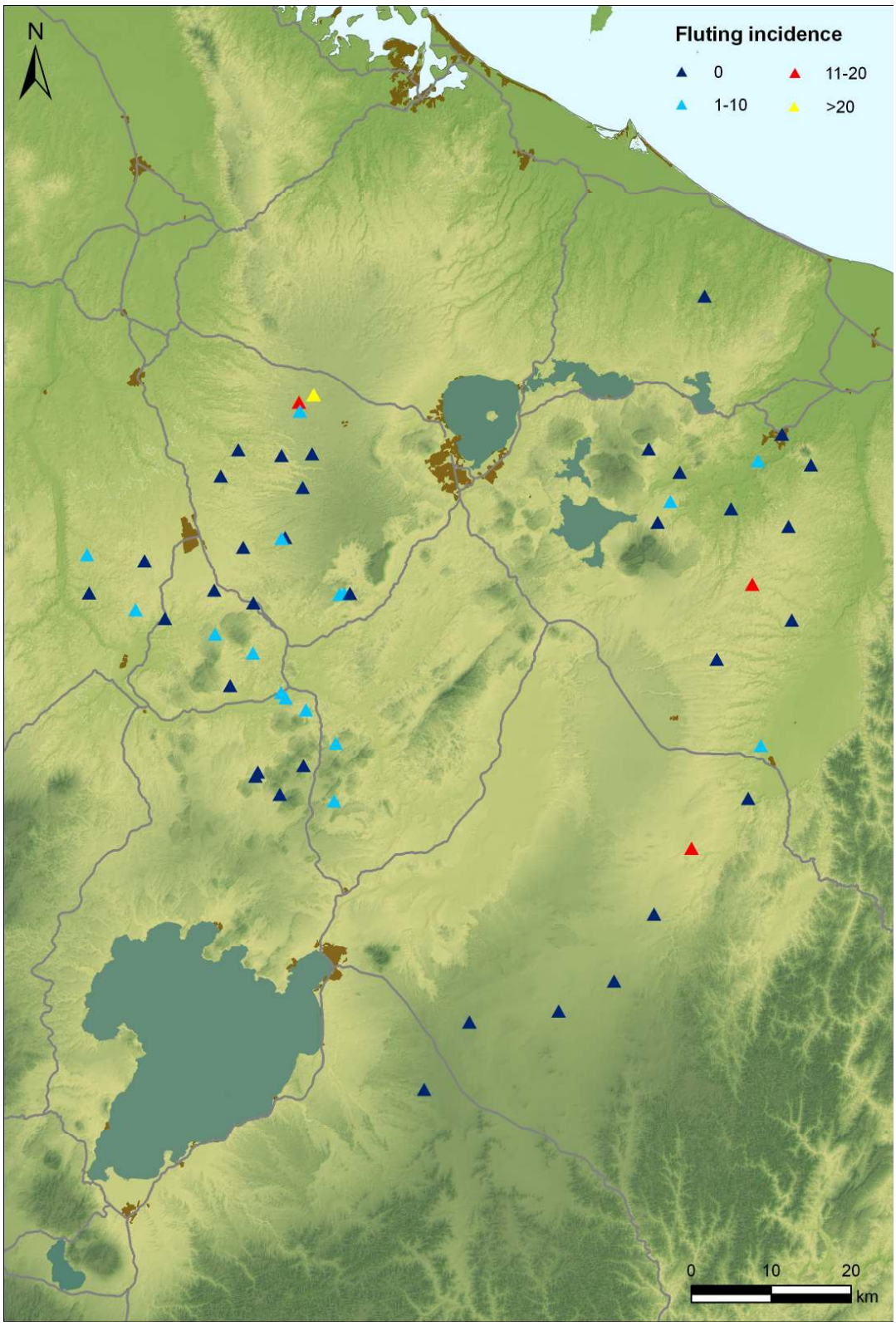


Figure 12 – Sampling points for the Central North Island survey October to November 2008, showing estimated percent of trees with fluting.

None of the surveys undertaken in Nelson and the central North Island have shown the presence of Nectria flute canker or the causal agent. The survey undertaken in the central North Island in 2008 was comprehensive and widespread (Figure 12). Five trees in each stand inspected were sampled, regardless of whether fluting was seen. A total of 135 samples were taken in Bay of Plenty forests and 160 were taken in Taupo forests. Fluting was common with just under 40% of the stands having fluted trees (Figure 12) but *N. fuckeliana* was not isolated.

Fluting seen in the central North Island was usually not severe and was often associated with large branch stubs. Symptoms were not typical of Nectria flute canker, for instance the flutes did not have rolled edges as seen in known infected regions. Fruit bodies or decay were not seen.

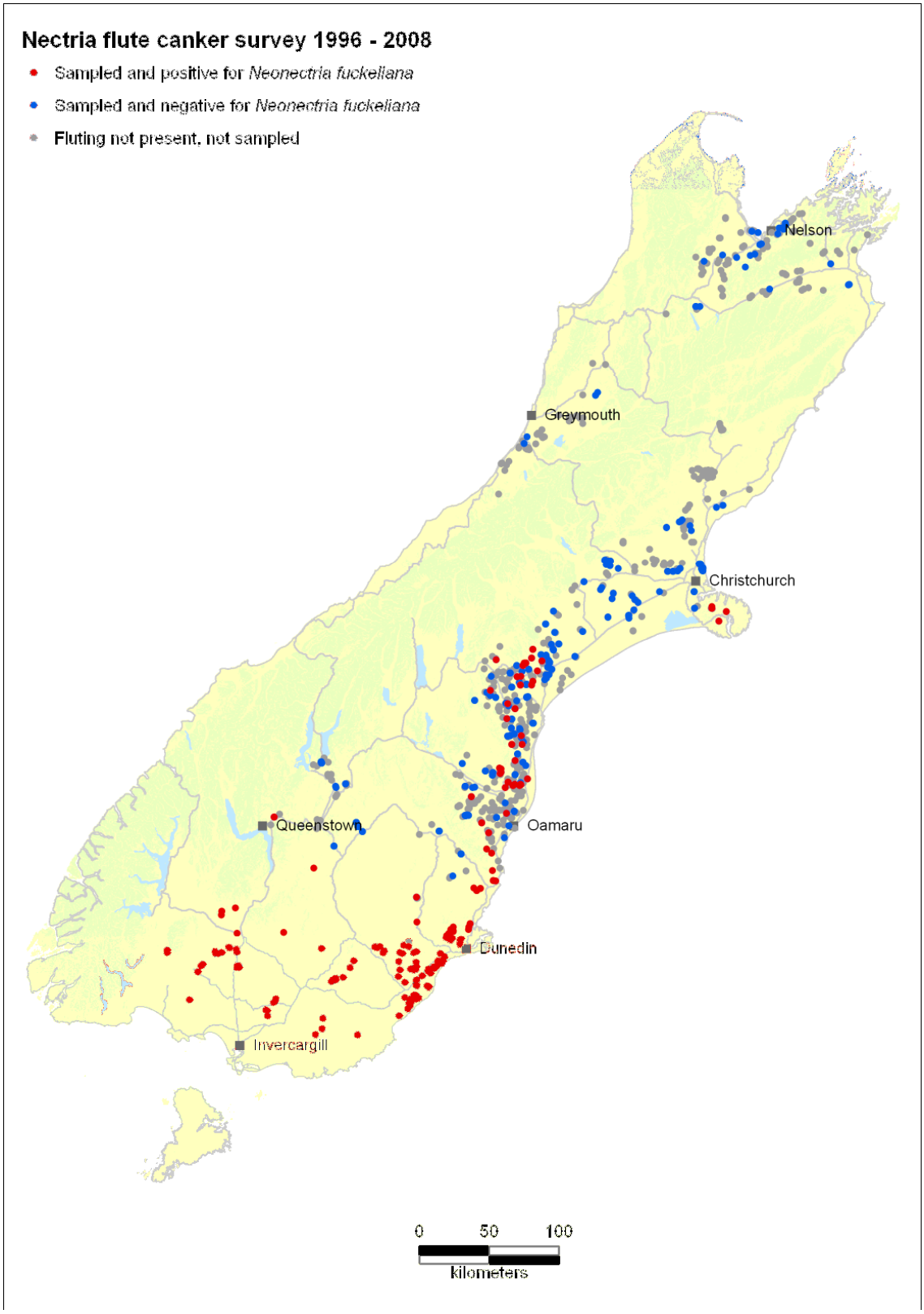


Figure 13 – Locations of *Neonectria fuckeliana* determined by forest health surveillance and delimiting surveys between 1996 and 2008.

Results of all South Island surveys are shown in Figure 13. The figure shows Banks Peninsula as the northernmost known location of *N. fuckeliana*. There is a considerable gap between there and the nearest known location near Geraldine in South Canterbury. The incidence of the fungus is lower in Canterbury than in Southland or Otago, which suggests that the known infected area is a good estimation of the actual infected area.

The apparent contradiction between distribution and spread of the fungus as determined by surveys and the finding that the fungus is present in trees pruned in the 1980s is puzzling. Dissection of mature trees throughout the known infected area might provide some useful information on which to determine when and where the fungus was introduced into New Zealand.

CONCLUSIONS

1. Forest health surveillance is not aimed at determining the incidence and distribution of forest diseases or pathogens. There is also evidence to suggest that *N. fuckeliana* was present in Southland and Otago in the early to mid 1980s. However, observations from routine forest health surveillance conform with data from the delimiting surveys and both show that the fungus spread throughout the lower South Island first, and then northwards.
2. The spread of *N. fuckeliana* appears to have slowed in Canterbury.
3. By the end of 2008, the fungus has spread as far north as Banks Peninsula.
4. Delimiting surveys undertaken in the central North Island did not detect *N. fuckeliana*

ACKNOWLEDGMENTS

Paul Cox carried out most of the delimiting survey assessments in 2005 and 2006. The remainder of the surveys were carried out by SPS Biosecurity and Forest Health Dynamics personnel. In 2008 and 2009 Dave Henley and Steve Pearce from Scion carried out surveys in Canterbury and central North Island, respectively. Everyone's efforts are gratefully acknowledged. Rita Tetenburg was primarily responsible for the sample processing and data recording, and Lucy Manning produced the distribution maps. Anna Hopkins made many useful suggestions on the draft and her help is appreciated.

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