"SIX MONTHS IN A LEAKY BOAT": THE BIOSECURITY OF NEW ZEALAND FORESTS*

G. S. RIDLEY

New Zealand Forest Research Institute,
Private Bag 3020, Rotorua, New Zealand

(Received for publication 4 March 2004; revision 3 May 2004))

ABSTRACT

New Zealand is a large, isolated, oceanic, temperate, continental fragment — characteristics that have resulted in a distinct but depauperate flora also lacking virulent forest pathogens. This grand isolation has protected its native forest from any obvious natural incursions by pathogens, while affording a similar protection to the large array of exotic tree species that have been imported since the arrival of European colonists in the early nineteenth century. What is unique about the biological, social, technological, and economic factors that have historically afforded this protection? Have these factors undergone rapid change in recent years, and as a consequence is New Zealand becoming more vulnerable to border breaches and invasion by forest pathogens? Where are the most likely sources of these pathogens? And what of the enemy within? Do we harbour "sleeper pathogens" that may explode as the mitigating nature of these controlling factors changes? These questions were addressed in recent research programmes that evaluated (1) the importance of suspected pathways whereby foreign biota could breach New Zealand's border, (2) the recognised north-south and east-west dispersal patterns of historical pathogen invasions, and (3) an example of a "sleeper pathogen" *Phaeophleospora eucalypti* (Cooke & Massee) Crous, F.A.Ferreira & B.Sutton.

Keywords: biosecurity; geography; biology; sociology; economics; sleeper pathogen.

INTRODUCTION

Aotearoa, rugged individual
Glisten like a pearl
At the bottom of the world
The tyranny of distance
Didn't stop the cavalier

"Six Months in a Leaky Boat"
Tim Finn / Split Enz 1982.

"Six Months in a Leaky Boat" is the title of an iconic New Zealand pop song of the 1980s which epitomises the physical, biological, social, and economic isolation of this ancient

* Paper presented at the 8th International Congress of Plant Pathology, 2–7 February 2003, Christchurch, New Zealand.

land mass. New Zealand's isolation ended a thousand years ago when the first humans arrived and its "distance" from the rest of the world is diminishing rapidly through globalisation. Globalisation has increased the volume of trade goods and the number of people moving at ever-increasing speed around the planet, thus increasing the threat of biological invasion (Biosecurity Council 2003). Yet prior to these changes, at least from a forest and tree pathology perspective, the number of invaders establishing in New Zealand has been very small. Is this due to New Zealand's physical, biological, social, and economic isolation? Is globalisation going to change this?

New Zealand is an archipelago located in the South Pacific Ocean with the three main islands extending from 34°S to 47°S, and is some 1600 km east of the nearest continent, Australia. With a land area of 269 063 km^2 it is similar in size to Japan (378 000 km^2) or Britain (244 000 km^2). It is composed of two main islands, the North Island and the South Island, and a number of small outlying islands (Table 1). New Zealand's climate has a marked maritime influence with an average temperature range from 8°C in July to 17°C in January, and rainfall of 400 mm in Central Otago to over 12 000 mm in the Southern Alps (McKenzie 1987; Statistics New Zealand 2003b).

TABLE 1–Land area (Statistics New Zealand 2003b)

	Size (km^2)
North Island	113 729
South Island	150 437
Offshore islands*	1 065
Stewart Island	1 680
Chatham Islands	963
Raoul Island	34
Campbell Island	113

* Includes all offshore islands 20 km^2 or larger, except those listed separately.

Geologically, New Zealand was formed from sediments laid down on the sea floor adjacent to the eastern coast of Australia and Marie Byrd Land (part of Antarctica). During the middle to late Jurassic (165–145 million years ago) these sediments were first formed into an ancestral New Zealand continent. It was at this time that the ancient elements of the New Zealand forests (*Agathis australis* (D.Don) Lindl., other Araucariaceae, and the Podocarpaceae) became established. Then during the middle Cretaceous (100–90 million years ago) the proto Tasman Sea and Southern Ocean began to open between the New Zealand continent and the remainder of Gondwanaland. Towards the end of this period *Nothofagus* species arrived via Marie Byrd Land. Over the next 90 million years the New Zealand continental land mass, as an ever-changing archipelago of islands subjected to climatic shifts ranging from glacial to tropical (Brazier *et al.* 1990), drifted further away. Warm conditions facilitated the colonisation of New Zealand by *Cocos*, *Eucalyptus*, *Casuarina,* and *Acacia* spp. However, when conditions became unsuitable during the ice ages these genera either failed to find suitable refugia or, if they did, failed to migrate out of those refugia when conditions became more suitable (Wilkinson 1999; McGlone *et al.* 2001; Lyford *et al.* 2003).

Thus, New Zealand can be described as an isolated, oceanic, temperate, continental fragment. It is these characteristics that have formed a distinct but depauperate indigenous flora of approximately 2100 native species (Nicol 1997) of which 232 are considered to form trees* (Salmon 1980). These trees form two dominant forest types, the conifer-hardwoods characterised primarily by Podocarpaceae, and southern beech forest characterised by one or more of four species of *Nothofagus*. New Zealand's grand isolation has provided protection to its forests from incursions by exotic pathogens and has also resulted in a distinct lack of virulence amongst its indigenous pathogens. The New Zealand populations of tree species can be seen as a metapopulation consisting of a set of semi-isolated populations (Rosenzweig 2003). Some of these populations will be self-sustaining and the source of emigrants to other populations. The remainder will not be self-sustaining in the long term and may die out within their range from time to time, at which point immigrants from self-sustaining populations may initiate new populations within the old range. This is an ideal situation for a species when its metapopulation ranges over a contiguous and hospitable landmass. However, over time New Zealand has frequently been reduced to a scattered archipelago and had periods with a cool climate. During these phases many of the isolated sub-populations would have teetered between sustainability and non-sustainability. If a virulent pathogen is added to this mix then it would quickly make its host population unsustainable and possibly lead to its extinction. As most pathogens are limited to one host or only a few (Ridley *et al*. 2000), the extinction of the host would result in the pathogen's extinction also. In these situations evolution will select for non-virulence, ensuring the survival of both host and pathogen (Zimmer 2003).

Although some diseases of exotic plantation and amenity trees have become established, such as *Dothistroma pini* Hulbary, *Cyclaneusma minus* DiCosmo, Peredo & Minter, *Melampsora larici-populina* Kleb., and *Ophiostoma novo-ulmi* Brasier (Ridley & Dick 2001), there have not been any significant epiphytotic events, comparable to those in the Northern Hemisphere, affecting either exotic or indigenous tree species in New Zealand (Ridley *et al.* 2000). This poses the question as to what is unique about the biological, social, technological, and economic factors that have historically afforded this protection? And further, have these factors undergone any change in recent years, and consequently is New Zealand becoming more vulnerable to border breaches and invasion by forest pathogens? The factors that have protected New Zealand can be organised into four interconnected groups — biological, social, technological, and economic factors.

BIOLOGICAL FACTORS

New Zealand's forests are cool temperate rainforests dominated by Podocarpaceae, Araucariaceae, Nothofagaceae, Myrtaceae, Cunoniaceae, and Lauraceae. Since the arrival of the first humans in approximately 1100–1200CE† (McLean 2001; King 2003) major changes to the forest cover have occurred with a reduction from almost 100% to 50% in

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* Salmon (1980) defined a tree as "a woody perennial plant with a stiff, erect and woody trunk which carries the branches above and clear of the ground … Under certain conditions some New Zealand shrubs can produce a trunk and grow into a small tree".

† In recent years a secular notation for dates, BCE (Before the Common Era) and CE (Common Era), has been used instead of the traditional BC and AD (Geering 1999)

1840 (Trotter & McCulloch 1997), and since then a further reduction to 23% (Leathwick *et al.* 2003). Much of the modified 77% is now covered by a mixture of mostly Northern Hemisphere plants in the form of pasture and some exotic forests achieved through a process that is best described as "the gardening of New Zealand"*.

Although much has been written about biological invasion it amounts to little more than a catalogue of disasters with lurid titles, i.e., "Alien Invaders" (Collard 1996), "Life Out of Bounds" (Bright 1998), "Feral Future" (Low 2001), and "A Plague of Rats and Rubber-vines" (Baskin 2002), with little real analysis of the case studies presented. It should be emphasised that the great failure of these compilations was to lump together all invaders, whether a mammalian predator or a host-specific leaf pathogenic fungus, and to treat them as equivalent. In comparison, Ridley *et al.* (2000) looked for patterns in narrowly defined taxonomic and ecological groups of invaders. The review was restricted to pests that attacked stems and foliage of indigenous tree species. The study showed:

- an east-west movement of pathogens in the Northern Hemisphere to closely related hosts,
- that there was no such north-south movement across the equator (except where the hosts had been transplanted, e.g., *Fusarium circinatum* Nirenberg & O'Donnell on *Pinus* spp. in South Africa and Chile), and
- that there was no such east-west movement recorded in the Southern Hemisphere.

The conclusion of this review was that real threats to New Zealand's indigenous forest would come from the endemic mycoflora of the Southern Hemisphere. However, the threats to its exotic trees would come from the Northern Hemisphere, including the possibility that some other area of the Southern Hemisphere could be a stepping stone, e.g., *Melampsora larici-populina* became established on exotic poplars in Australia and was then blown to New Zealand (Close *et al*. 1978). This example emphasises that for New Zealand biosecurity is a regional concern.

Biosecurity

Protecting New Zealand from biological invasion is called biosecurity: this term has, however, been in use only since 1990 (Biosecurity Strategy Development Team 2001). Despite the fact that it had been enshrined in the "Biosecurity Act", in a Government Minister for Biosecurity, and in a Biosecurity Council, there was no single accepted definition for "biosecurity" between 1990 and 2002 (Parliamentary Commissioner for the Environment 2000). A definition has only recently been formalised by the Biosecurity Council (2002, 2003) and it is now defined as "…the system for the prevention, eradication and management of the risks posed by pests and diseases to the economy, the environment, and human health".

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* There are now approximately 160 alien species that require some form of control in New Zealand, 1900 adventive species that require weed risk assessment, and a further 18 000 species in cultivation, of which at least 4000 have been listed as weeds in other countries (Williams *et al.* 2001).

SOCIAL FACTORS

The initial colonisation of New Zealand by the Maori probably had no effect on the pathology of New Zealand's forests as the migration would have been almost exclusively one way and limited. In contrast, the European colonisation which began in 1840 was much more frequent and in both directions. Yet no significant pathogen made the journey! This could be simply good luck or, equally, social factors can be invoked. New Zealand was part of the British Empire and as such was focused on mother England. This focus is illustrated in the early writing of Katherine Mansfield, who in 1907 compared New Zealand with England (Stafford & Williams 2002):

> I know the bush is beautiful
> The cities up to date
> in life, they say, we're on the top
> it's England, though, that's late.
> But I, with all my longing heart,
> I care not what they say
> It's London ever calling me
> the live long day.

With Pakeha* New Zealanders firmly focused on England and the Empire, the resulting movement in people and cargo to New Zealand initially followed a trade route via South Africa and Australia which provided a tropical and Southern Ocean filter. In the 1850s the "great circle route" was pioneered, with ships penetrating deep into the frigid Southern Ocean to ride the Roaring Forties before making first landfall in New Zealand in as little as 76 days (Watson 1996: McClean 2001). With the opening of the Suez and Panama Canals, the length of voyages to New Zealand was shortened but the period of time spent in the tropics increased, reducing the survival chances of any pathogens on board. New Zealand's allegiance to Britain continued through the twentieth century. In 1924 the Governor-General noted that New Zealanders "claim, in fact, to be even more British than their kin of the Motherland". Then in 1939 Prime Minister Michael Savage said when declaring war against Germany (King 2003):

> "With gratitude for the past and confidence in the future we range ourselves without fear beside Britain. Where she goes, we go; where she stands, we stand."

However, at the end of the Second World War a new sense of nationalism had been kindled and there was "a growing Pakeha appetite for information about their historical and cultural links with New Zealand and a growing curiosity about the developing nature of their connection with the land" (King 2004). Despite this, New Zealanders prolonged their adolescence and continued to wait "expectantly for a British-flag Conference Line ship to ferry out the next shipment of Matchbox toys or *Beano* comics" (McLean 2001). It would take severe economic changes to force the final steps to the current situation where very few Pakeha New Zealanders would consider themselves British.

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* According to Ranford (2004): "Pakeha is used to describe any peoples of non-Maori or non-Polynesian heritage. Pakeha is not an ethnicity but rather a way to differentiate between the historical origins of our (New Zealand's) settlers, the Polynesians and the Europeans, the Maori and the other".

TECHNOLOGICAL FACTORS

As already stated, the voyage from England to New Zealand via the Cape of Good Hope in the mid-nineteenth century was both perilous and long, taking from 3 to 6 months (Belmer1971; Holcroft 1971; Bellich 1996; McLean 2001; Lockyer 2002). This is in stark contrast to the current 24-hour trip from London to Auckland in a fully environmentally controlled airliner. In 1769, when James Cook and his men landed at Poverty Bay (Hough 1994), it could be said that temporally New Zealand was 80 million years removed from Australia. Approximately 200 years later in 1965 TEAL (the fore-runner of Air New Zealand) and Qantas began the first jet passenger service to Australia and dramatically reduced this temporal disjunction to about 4 hours (Denton 1973, Driscoll 1979; Lowe 1981; Brimson 1984). The rise of the passenger jet in the early 1970s also spelt the death of the passenger liners; as expressed by McLean (2001) "the rite of passage, sailing to and from Britain in a British passenger liner, was over". Port facilities languished until the 1990s when cruising became fashionable and once again passenger liners began calling at both major and minor ports. These ships are now arriving from ports around the South Pacific, they are environmentally controlled and often do not pass through the old tropical and Southern Ocean filters. In 1990 fewer than 1 million people visited New Zealand; this rose by 85% to 1.8 million in 2000, and it is projected that by 2010 this will have risen by 81% to 3.2 million (Tourism Strategy Group 2001). It is likely that these visitors will be more mobile and penetrate deeper into the heartland than ever before, thereby substantially increasing the biosecurity risks to New Zealand's forests.

Containerisation of cargo brought another revolution, with container ships having a turn-around time of a few days, compared to conventional cargo ships with a 4- to 6-week turn-around time. By the end of the 1970s container ships had almost completely replaced conventional freighters (McLean 2001) and greatly reduced the number of international ships visiting New Zealand ports and the number of ports visited. But the Government policies of the 1980s greatly increased the range and amount of goods being imported. This rapid increase in trade resulted in a number of studies to quantify the biosecurity risks posed by both sea and air containerisation of cargo. Bulman (1992, 1998) surveyed the contaminants inside sea containers, Gadgil *et al.* (2000) looked at contaminants on the external surfaces of sea containers, and Gadgil *et al.* (2002) examined the risks associated with air containers. In the latter study, 991 air containers were examined, and 131 or 13.1% were contaminated. By region of origin 18.2% of the Australian containers contained contaminants, 16.4% of those from Europe, 9.4% from North America, 5.9% from South-east Asia, and 5.1% from Pacific nations.

ECONOMIC FACTORS

Between 1880 and 1940 New Zealand's world-view was British and so, not surprisingly, the bulk of New Zealand's trade was with Britain. So pervasive was this attitude that Belich (1999) felt that New Zealand had "become London's town supply district; London became New Zealand's cultural capital; refrigerated meat ships bridged the gap as if inter-island ferries of a single entity … The favourite child traded prolonged adolescence for special access to Mother's ear, purse, and markets, and for higher living standards". This was largely the case until the 1970s when Britain joined the EEC and turned its back on its old colonial trading partners, a position which has been given greater priority with globalisation.

As Prime Minister Bill Rowling said after trade negotiations in London 1975: "The old simple dependent relationship has gone forever" (Henderson 1981). Since then New Zealand's import trade has increasingly moved away from Britain towards Australia, Asia, and North America (Ridley *et al.* 2000). Between 1920 and 1960 approx 50% of imports were derived from Britain (McLean 2001) whereas in 1999, of the top 10 sources of New Zealand's imports, Britain ranked fifth with 6.5% of trade value (Statistics New Zealand 2003a). In recent years a number of trade missions have been to South America, a continent with which New Zealand has traditionally had little contact, in an endeavour to increase trade. An increase in trade along this pathway has significant biosecurity implications for New Zealand, as stated above (Ridley *et al*. 2000).

AND WHAT OF THE ENEMY WITHIN?

Weed ecologists have the term "sleeper weeds" which they apply to species that have established at a low level and may sit for decades before exploding into a major problem (Panetta *et al.* 2001). Do we harbour "sleeper pathogens" that may explode as the mitigating nature of the outlined controlling factors changes? An example of changing governing factors resulting in a new disease situation occurred with plantings of *Eucalyptus nitens* (H.Deane & Maiden) Maiden in New Zealand. This species from south-eastern Australia occurs naturally above 600 m a.s.l. and was introduced into New Zealand in the 1920s (Miller *et al.* 1992). A series of trial plantings were carried out in the central North Island in the 1970s to determine its potential as a source of short fibres for the pulp industry to replace indigenous species as logging of native forests was phased out. Unfortunately, these plantings were decimated by the eucalyptus tortoise beetle *Paropsis charybdis* Stål, and as a result further plantings of *E. nitens* were not recommended. Then in 1990 the first effective biological control for the eucalyptus tortoise beetle was heralded (Forest Research Institute 1990) and *E. nitens* had a new lease of life. Forest Research was approached in the mid-1990s about the suitability of *E. nitens* as a short-rotation plantation species in the Bay of Plenty and Taupo regions in order to reduce transport costs to the pulp mill. As many of the plantings would be below 600 m and in warm, humid, coastal areas, a warning was given that species of *Mycosphaerella*, particularly *M. cryptica* (Cooke) Hansf., could be a serious problem on juvenile foliage (M.Dick pers. comm.). The plantings went ahead and the trees suffered severe defoliation. However, much of the defoliation was caused by *Phaeophleospora eucalypti*, a fungus which had been considered to be only a very minor pathogen since it was first recorded in New Zealand in1981 (Hood *et al.* 2002). Here was a fungus that we thought we knew; the host's range was stretched to its limits to meet economic constraints, resulting in a disease outbreak. *Phaeophleospora eucalypti* is a typical sleeper pathogen and it begs the question: when will other sleepers, both unrecorded and recorded as present in New Zealand, blow up in our faces? In this example it was the planting of the host species in an inappropriate environment that caused a problem. However, in the future it may be global warming effects that trigger the transformation of sleeper pathogens into virulent pathogens (Harvell *et al.* 2002).

FINALE

Risk assessments for specific commodities and pathogens are important; however, it is just as important to understand the larger socio-economic environment over space and time

if we are to understand the "what", "how", and "why" of potential incursions of the future. Notwithstanding this knowledge, and no matter how prepared we attempt to be, it may still be possible for a totally unpredicted pathogen to enter New Zealand, take hold and devastate. As Bain so rightly said "It is unwise to focus too much attention on individual organisms. More importantly, we should be maintaining a broad knowledge base and cleaning up pathways so that pests of all kinds are prevented from entering the country in the first place" (Forest Research 2003).

ACKNOWLEDGMENTS

The author thanks all of his Forest Health colleagues, especially those whose work has been drawn from: Lindsay Bulman, Sandra Chapman, Margaret Dick, Peter Gadgil, and Ian Hood. Funding was provided by the Foundation for Science, Research and Technology.

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