Proceedings of the 7th and 8th Symposia on Collection Building and Natural History Studies in Asia and the Pacific Rim, edited by Y. Tomida *et al*., National Science Museum Monographs, (34): 37–49, 2006.

New Zealand's Nonlichenised Fungi—Where They Came from, Who Collected Them, Where They Are Now

Peter R. Johnston

Herbarium PDD, Landcare Research, Private Bag 92170, Auckland, New Zealand
(e-mail: johnstonp@landcareresearch.co.nz)

Abstract About 6,500 species of nonlichenised fungi have been reported from New Zealand. About 4,500 of these are indigenous and 2,000 exotic. Most of the exotic species have been accidentally introduced over the last 200 years. The exotic species are largely restricted to human habitats, although examples of two well-known species which have become widely naturalised are discussed. It is estimated that approximately 15,000 indigenous species remain to be discovered, described, and named. Of those which are known, about half are endemic. The origins of the indigenous species are diverse, some being an ancient component of New Zealand's biota, derived from Gondwana, others are local endemics which evolved following New Zealand's separation from Gondwana, and others are geologically recent introductions through natural long distance dispersal. The scientific collecting of New Zealand's fungi started with European colonisation in the mid-1800's, but it was not until the 1920's, with the appointment of New Zealand's first resident mycologist, that systematic studies of targeted groups of fungi were initiated. The New Zealand Fungal Herbarium (PDD) was established at the same time. PDD is now the largest collection of New Zealand fungi in the world. The collection contains about 80,000 specimens, about two-thirds of these from New Zealand, including 2,000 type specimens. PDD also contains a large number of voucher specimens validating disease records from the Pacific Islands. Associated with the herbarium is the ICMP culture collection, established during the 1960's. Both collections are fully databased. The NZFungi database contains records of all names used for fungi in a New Zealand context, publication details of those names, the specimens, cultures and literature records supporting the use of those names in New Zealand, and synonymy with an indication of the current preferred name. It also contains descriptions and images of many of these fungi. In this paper data is extracted from NZFungi to illustrate the numbers of fungi that have been described from New Zealand historically, the people making those descriptions, the places that collections of the fungi have been stored, and the kinds of fungi that have been targeted for research.

Key words: database, ICMP culture collection, indigenous fungi, NZFungi, PDD.

Introduction

This paper discusses the origins of New Zealand's nonlichenised fungi, the scientific collection and description of those fungi, the herbaria in which the collections are stored, and the electronic data available from those herbaria.

New Zealand's geological and cultural history has resulted in New Zealand's biota comprising several different components:

– an ancient component derived from the supercontinent Gondwana;
– local endemics which evolved during New Zealand's long-isolated but geologically turbulent history;

– geologically recent introduction following natural transoceanic dispersal;
– deliberate or accidental introduction of new organisms following human colonisation.

Although the origin of New Zealand's fungi has barely been investigated compared with other groups of organisms, New Zealand's fungal biota appears to reflect these same diverse influences.

Once part of the supercontinent Gondwana, New Zealand has an ancient component to its biota, derived from it sharing a landmass with modern-day South America, Australia and Antarctica. New Zealand separated early from the rest of Gondwana, being isolated by sea for about 80 million years. This length of isolation is reflected in high levels of endemism for some groups of organisms (Stevens 1980). A period of marine transgression during the Oligocene resulted in the loss of much of New Zealand's ancient biota. New Zealand at that time was a series of highly-eroded, low-lying island archipelagos, the total land area estimated at about 18% of the present day (Cooper & Millener 1993). Following this period, the Pacific and Indian-Australian plates started to push against each another in the New Zealand region, the increasing levels of tectonic pressure and volcanism leading to New Zealand's present-day mountainous landscape (Stevens 1980, Cooper & Millener 1993). This rapidly changing and fragmenting landscape provided evolutionary opportunities resulting in high levels of species-level endemism in some groups. The impact of the Oligocene transgression on New Zealand's biota, the resultant genetic bottleneck, and following evolution of local endemics, has been demonstrated genetically for both birds (Cooper & Cooper 1995) and insects (Trewick & Morgan-Richards 2005). A similar impact is likely to have occurred on New Zealand's fungi, although for both the fungal and plant biotas, trans-oceanic dispersal from Australia and Asia has also been very important in shaping the biodiversity seen in New Zealand today.

New Zealand's human history has been short, discovered by the original Polynesian settlers about 800–1000 years ago, followed by colonisation from Europe in the last 200 years. Both groups of settlers introduced economically useful animals and plants, and along with these came large numbers of accidentally introduced microbes and insects. The colonisation of New Zealand from Europe also saw the start of scientific collecting of New Zealand's fungi. However, systematic studies of targeted groups did not start until the 1920's, with the appointment of New Zealand-based mycologists. This history is briefly discussed, along with the scope of the collections stored in the New Zealand Fungal Herbarium (Herbarium PDD), and the data available from that collection.

New Zealand's Fungi—Where Did They Come from?

It is estimated that New Zealand has about 20,000 species of native fungi, although many of these remain undiscovered and unnamed. About 6,500 species of fungi have been recorded from New Zealand, and of these about 4,500 are thought to be indigenous (data from http://nzfungi.landcareresearch.co.nz). About half of the indigenous species are putatively endemic.

Ancient Taxa from Gondwana

Present-day distributions suggest that some fungi are likely to be part of New Zealand's ancient biota, occurring in New Zealand since before the breakup of Gondwana. These could include ascomycetes such as *Corynelia* (restricted to the largely Southern Hemisphere genus *Podocarpus* and found throughout the range of *Podocarpus*), *Bivallum* (restricted to Podocarpaceae and Southern Hemisphere Cupressaceae and found in New Zealand, Australia

and South America), and basidiomycetes such as *Rozites* (Bougher *et al.*, 1994). The *Nothofagus* pathogen *Cyttaria* has also been thought of as an ancient part of New Zealand's biota (Buchanan *et al.*, 2005). Species of *Cyttaria* are restricted to *Nothofagus* subgenus *Lophozonia* and *Nothofagus* subgenus *Nothofagus*, and are found throughout the range of these plants, in southern South America, Australia, and New Zealand (Gamundi 1991). However, recent studies have shown that although *Nothofagus* lineages have been in New Zealand since the split from Gondwana, the ancestor of *N. menziesii* (the only host of *Cyttaria* in New Zealand) arrived following long distance dispersal from Australia (Knapp *et al.*, 2005). *Cyttaria* presumably arrived in New Zealand after its host had become established.

No studies providing genetic evidence for ancient biogeographic relationships of any New Zealand fungi have been published. Fig. 1 presents data from an unpublished study of the inoperculate discomycete genus *Torrendiella*. These fungi are common and diverse in New Zealand and Australia, both countries having many host-specialised species, most of them undescribed. Within the genus there are host-specialised, monophyletic clades comprising groups of species that have apparently diverged following their common ancestor adapting to life on the host that they share. Clade 1 includes 5 species specialised to *Nothofagus*, 4 from New Zealand and one from South America. Amongst these 5 species sequence divergence is 7% and 12% between pairs of species (4 genes sequenced, ITS, lsu rDNA, CAL, CHS, with an alignment length of 1898 bp). The sequence divergence between the *Nothofagus*-inhabiting species is greater than between a set of *Metrosideros*-inhabiting species (Clade 2, sequence divergence 2–3%), thought to have

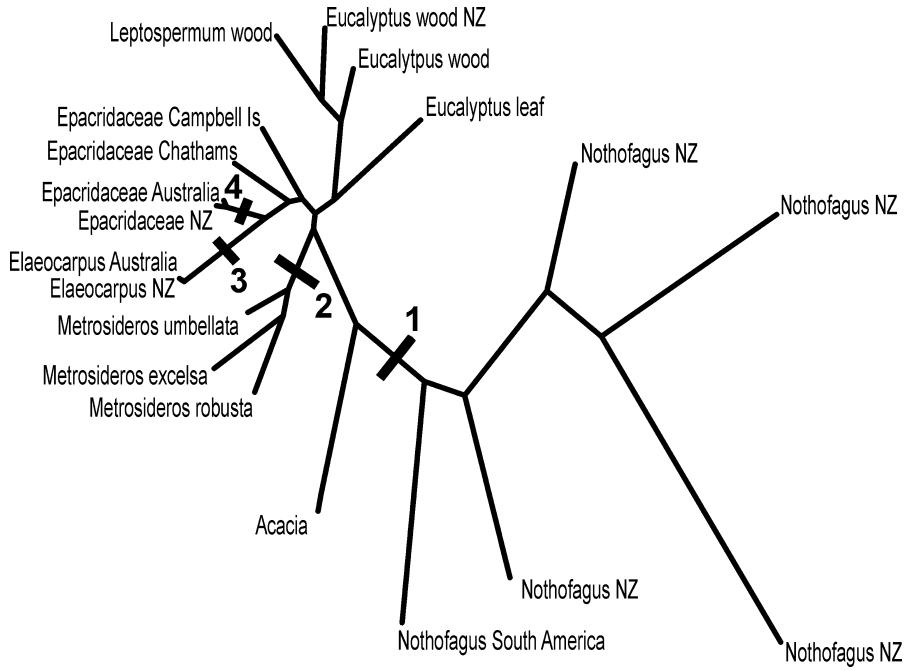

Fig. 1. Phylogeny of the discomycete genus *Torrendiella*. Each major terminal branch represents a different species, the species labelled with the host on which they are hound. One of the 3 shortest maximum parsimony trees based on DNA sequences from ITS, lsu rDNA, CAL, and CHS genes. The alignment was 1898 bp. Clade 1 is the *Nothofagus* clade, Clade 2 the *Metrosideros* clade, Clades 3 and 4 contain representatives of the same species from Australia and New Zealand, from *Elaeocarpus* and Epacridaceae respectively. See text for explanation.

evolved within New Zealand within the last 30 million years (age of divergence based on divergence of hosts, data from Wright *et al.*, 2000). This dates the ancestor of the *Nothofagus*-inhabiting *Torrendiella* species at about 80 million years, potentially one of New Zealand's "ancient" fungi. If these are truly ancient fungi, then they have presumably been able to adapt to life on a range of different *Nothofagus* species, switching hosts as a succession of the tree species became locally extinct.

Local Endemics

Fungi are one of the potentially more mobile groups of organisms, a factor which would seem to work against vicariant speciation through geographic isolation. Despite this, geographic structure is seen in fungal populations. Examples include *Fusarium graminearum* (O'Donnell *et al.*, 2004), *Heterobasidion annosum* (Johannesson & Stenlid, 2003), *Strobilomyces* (H. Sato, pers. comm.), and *Lophodermium pinastri* (Johnston *et al.*, 2003a). One explanation for such patterns is that they are driven by isolation through host specialisation rather than geography (Johnston & Gamundi, 2002, Johannesson & Stenlid, 2003).

Torrendiella species on *Metrosideros* (Fig. 1, clade 2) provide a New Zealand example, with three morphologically similar but genetically distinct species occurring on three closely related *Metrosideros* species, *M. excelsa*, *M. robusta*, and *M. umbellata*. The *Metrosideros* species diverged around 30 million years ago (Wright *et al.*, 2000) and the *Torrendiella* species associated with them have apparently diverged along with their hosts. The trees are endemic to New Zealand and as the three fungi are host-specialised, they are also endemic.

About half of the indigenous species recorded from New Zealand are putatively endemic (data from http://nzfungi.landcareresearch.co.nz). Those restricted to an endemic host species will necessarily never be found elsewhere, however many of the putative endemics are in poorly studied taxonomic groups and may in the future be found in other areas.

Trans-oceanic Dispersal

New Zealand and Australia share large numbers of species of fungi in groups such as the Rhytismataceae, Helotiales, and Agaricales. In addition, northern New Zealand shares a range of species with tropical Asia and tropical America, especially of species not limited by specialisation toward a single host substrate (Johnston, 1992). Although morphologically identical, the genetic identity of most of these broadly distributed taxa has yet to be investigated. A few that have been studied genetically include *Cookeina colensoi* (Weinstein *et al.*, 2002), *Pisolithus* species (Moyersoen *et al.*, 2003), *Torrendiella* spp. (Fig. 1, clades 3 and 4), and *Coccomyces radiatus* (P.R. Johnston, unpubl. data), all of which include genetically and morphologically identical individuals on both sides of the Tasman Sea. These taxa have dispersed very recently, or may even form a single population with regular trans-oceanic gene flow.

Lentinula dispersed to New Zealand within the last 10 million years (Hibbett, 2001). Since that time the New Zealand species *L. novaezelandiae* has become genetically distinct from species in Papua New Guinea and Australia (Mata *et al.*, 2001), the likely source of this fungus for New Zealand. Similarly, collections identified as *Armillaria novaezelandiae* show geographically distinct clades from New Zealand, Australia and tropical Asia (Coetzee *et al.*, 2001, 2003). This suggests that for some fungi at least, genetic transfer between the regions is a rare event, allowing time for the evolution of geographically distinct populations.

Northern/Southern Hemisphere Disjunctions

The geographic relationships of New Zealand's native fungi are strongly biased towards the Southern Hemisphere. Generally, there appear to be distinct Southern Hemisphere and Northern Hemisphere groups of fungi. Johnston (1992) gave an example at the species level, when of the 59 species of *Coccomyces* known at that time, 31 were confined to northern regions and 28 to southern regions. At higher taxonomic levels there also appears to be a northern-southern bias. For example there is a very low diversity of Pezizales (cf. data in Rifai, 1968) and Boletales (cf. data in McNabb, 1968) in New Zealand. Examples of groups with a much higher diversity than might be expected from Northern Hemisphere experience include the clavarioid subgenus *Holocoryne* (Petersen, 1988), and the discomycete genera *Chlorociboria* (Johnston & Park, 2005), and *Torrendiella*, which has several species described from *Nothofagus* (Johnston and Gamundi, 2000), plus at least another 12 undescribed species in New Zealand (P.R. Johnston unpubl. data).

There have been few phylogeographic studies of New Zealand's fungi, with most of the examples above being based on species-level observations. A phylogenetic study of the discomycete fungi *Chlorociboria* (Johnston & Park, 2005) suggested that this genus has its centre of diversity in the Australasian region. The few Northern Hemisphere species of *Chlorociboria* are near the tips of the tree. One of the most common Northern Hemisphere species, *C. aeruginascens*, is sister to the Southern Hemisphere *C. aeruginascens* subsp. *australis*, and this and the other Northern Hemisphere species may have dispersed northwards in relatively recent times.

An exception to the northern-southern split is provided by a species of *Armillaria*, where the Australasian *A. hinnulea* belongs in an otherwise Northern Hemisphere *Armillaria* clade (Coetzee *et al.*, 2001). There are many putatively cosmopolitan species of ascomycetes reported from New Zealand in genera such as *Ascocoryne*, *Bertia*, *Bisporella*, *Kirschsteiniothelia*, *Mollisia*, and *Nemania*. Whether genetic studies will support the validity of such apparently broad geographic distributions is unknown.

Human Introductions

Both the original Polynesian settlers of New Zealand and the later colonisers from Europe brought plants and animals with them. These animals and plants were introduced with no thought to quarantine, and large numbers of fungi were accidentally introduced along with them, especially during the period of European colonisation. About one-third of the 6,500 species of fungi at present known from New Zealand are thought to have been introduced by humans, the vast majority of these over the past 200 years.

These introduced fungi are almost exclusively restricted to human habitats, typically found in association with introduced plants or animals, with very few on native plants (Fig. 2). A few fungi known to be introduced, such as the wood-inhabiting saprobe *Favolaschia calocera* and the ectomycorrhizal *Amanita muscaria*, have become naturalised in native forests (Johnston *et al.*, 1998). The invasive nature of these species is known because they are highly visible and distinctive fungi. The rapid spread of *F. calocera* into native forests over the past 50 years makes it possible that other, less noticeable human-introduced fungi are also present in New Zealand's forests. An example of one of these might be the white, insignificant but widespread crust fungus *Schizopora radula* (Johnston, 2004). A genetic study by Paulus *et al.* (2000) showed New Zealand isolates of this fungus to be genetically identical to isolates from Canada. Those from other parts of the Southern Hemisphere were more closely related to other Northern Hemisphere populations than they were to those from New Zealand, suggesting multiple independent introductions to the south. Johnston *et al.* (2003b) suggested that Polynesian settlers may have introduced the now

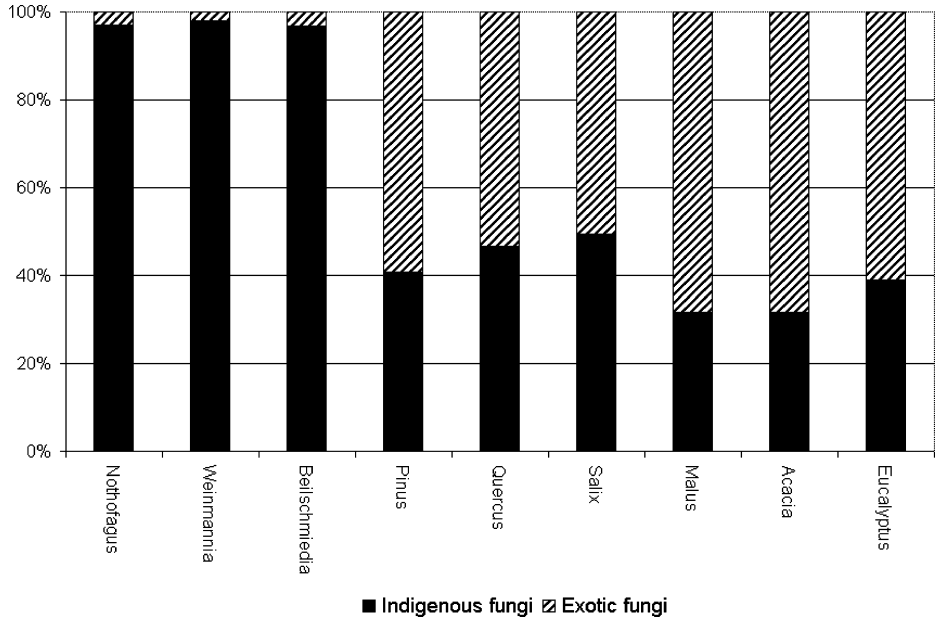

Fig. 2. The proportion of indigenous and exotic nonlichenised fungi on a range tree hosts, both indigenous (the 3 hosts to the left) and exotic (the 6 hosts to the right). Data based on collections of fungi from New Zealand in the New Zealand Fungal Herbarium (PDD). Very few exotic fungi have moved into native forests. In contrast, around 40% of the fungi reported from exotic trees are putatively indigenous.

widespread root pathogen *Phytophthora cinnamomi* with crop plants such as taro (*Colocasia esculenta*).

It is interesting that although few exotic fungi appear to have become established in native forests, the reverse is not true. Around 40% of the fungi recorded from a range of introduced woody plants are thought to be native to New Zealand (Fig. 2). Large numbers of fungi are apparently moving from the forests into human habitats, such as orchards and plantations. With this movement comes the potential for the development of new diseases. For example, native species of *Armillaria* cause problems with disease in plantations and orchards (Hood, 1989, Horne, 1985). Another example may be *Cryptosporiopsis actinidiae*, recently described as causing a rot of orchard fruits, but later discovered to be widespread in native forests (Johnston *et al.*, 2005). This orchard pest could be a native fungus with a biology 'pre-adapted' to causing diseases of commercially important plants.

New Zealand's Fungi - Who Collected Them?

The history of mycology in New Zealand can be divided into two distinct phases. In the first phase, prior to 1920, collections of fungi were made by naturalists attached to early scientific expeditions or by resident naturalists and explorers amongst the early settlers. These collectors were primarily interested in plants and animals, a few fungi being picked up at random with only passing interest. It may not be a coincidence that several of the early fungi described or reported from New Zealand were amongst the few species used by Maori (Fuller *et al.*, 2004) and were possibly brought to the attention of the early collectors by Maori. Examples include *Aseroe rubra*, *Cordyceps robertsii*, *Ileodictyon cibarium*, and *Auricularia cornea*. These early collec-

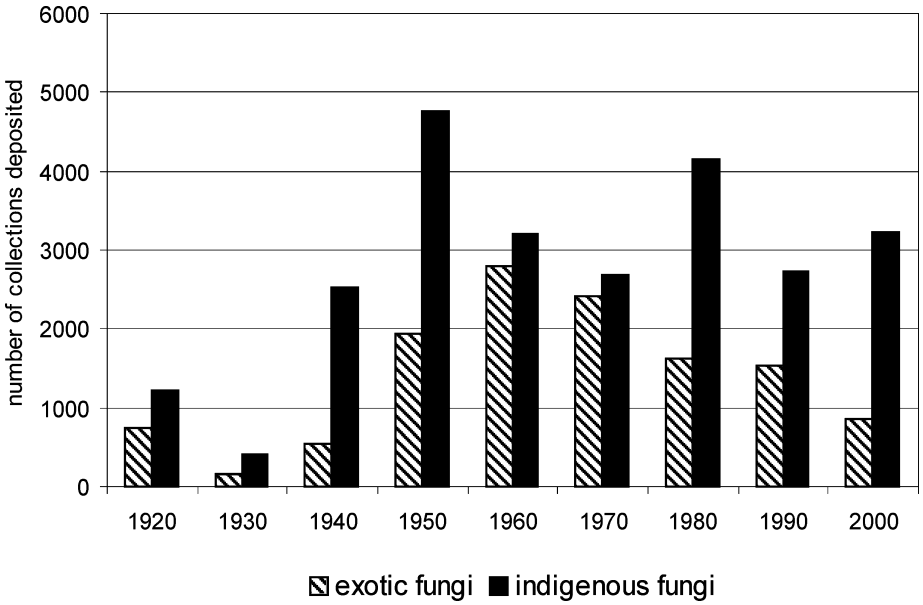

Fig. 3. Number of collections of exotic fungi and indigenous fungi deposited in the New Zealand Fungal Herbarium (PDD) for each 10 year period from 1920. The changing proportions of exotic versus indigenous fungi reflect changing research priorities of the mycologists associated with PDD. The 1960's and 1970's saw an increase in the proportion of exotic fungi deposited, these mostly being voucher specimens associated with disease records from commercially important crops. In recent years the focus has shifted towards the description of indigenous fungi.

tions were sent to European institutions for study, primarily to Kew Gardens. During this period 200–300 species of fungi were described from New Zealand (data from http://nzfungi.landcareresearch.co.nz).

The second phase started with the appointment of G. H. Cunningham as New Zealand's first resident professional mycologist. His appointment saw the start of disciplined, systematic studies of targeted groups of New Zealand fungi (McKenzie, 2004). Cunningham established New Zealand's first cryptogamic herbarium, his collection of fungi forming the basis of what is now the New Zealand Fungal Herbarium (PDD), maintained by Landcare Research. Although Cunningham's appointment was primarily as a plant pathologist he had a strong interest in the indigenous fungi of New Zealand and his most important publications relate to these. He deposited over 2,000 collections of fungi in PDD, described over 400 new species of fungi and reported many more for the first time from New Zealand. The herbarium has had a series of mycologists over the years, including Joan Dingley, Ross McNabb, Gary Samuels, Eric McKenzie, Peter Johnston, Peter Buchanan, and Ross Beever. In recent years the focus of the collection and associated staff has shifted towards indigenous fungi (Fig. 3). Research on applied plant pathology is now mostly carried out at other institutes, but the PDD herbarium is still used as the main repository for voucher and type specimens by these other researchers.

This remainder of this paper concentrates on the PDD herbarium, the staff associated with that herbarium, and the resources available through the herbarium. McKenzie (1983, 2004) can be consulted for a discussion of the broader history of New Zealand's taxonomic mycology.

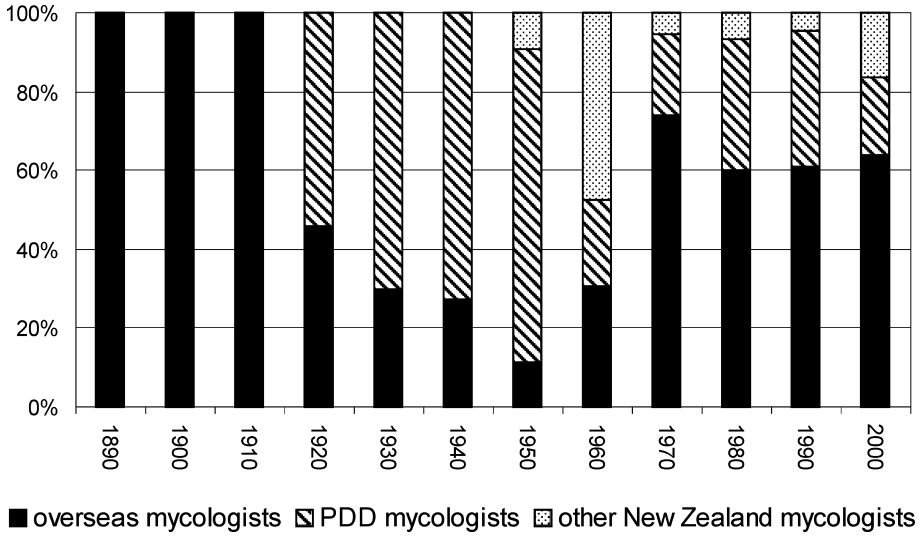

Fig. 4. Proportion of New Zealand type specimens described by New Zealand-based and overseas-based mycologists for each 10 year period from 1890. Of those described by New Zealand-based mycologists, the proportion described by mycologists attached to the New Zealand Fungal Herbarium (PDD) and those from other New Zealand institutes (based primarily at the Forest Research Institute, and in some years in some universities).

New Zealand's Fungi - Where Are They Now?

Prior to Cunningham's appointment all of New Zealand's fungi were described by overseas based mycologists, and few type collections made before 1920 are retained in New Zealand herbaria (Figs. 4, 5). The largest overseas collection of New Zealand fungi is at Kew Gardens, but there are also significant numbers of specimens in herbaria such as P, B, BPI, W, ZT, TNS, and TENN. This means that data associated with New Zealand fungal collections is spread widely and is often difficult to access. However, the development of web-accessible electronic catalogues, such as has been provided by TENN (http://tenn.bio.utk.edu/fungus/fungus.html), will make the data associated with these scattered collections increasingly available.

From 1920 through to the 1950's there was a steady increase in the proportion of New Zealand's fungi being described locally (Fig. 4). From the 1960's onwards, with increased ease of travel to New Zealand's isolated part of the world, there has been a reversal of that trend, with overseas based mycologists now publishing more than half of the fungi described from New Zealand in any one year. Most of these mycologists work in collaboration with PDD, and the majority of their type specimens are returned to PDD for storage (Fig. 5). Today PDD contains about 2,000 type specimens. The efforts of overseas researchers are an important component of the ongoing taxonomic research on New Zealand's fungi. Most local taxonomic research is carried out by PDD mycologists (Fig. 4). The 1960's showed a different pattern. During this decade Greta Stevenson (Victoria University) was active, and all of her type specimens were deposited in the Kew Gardens herbarium.

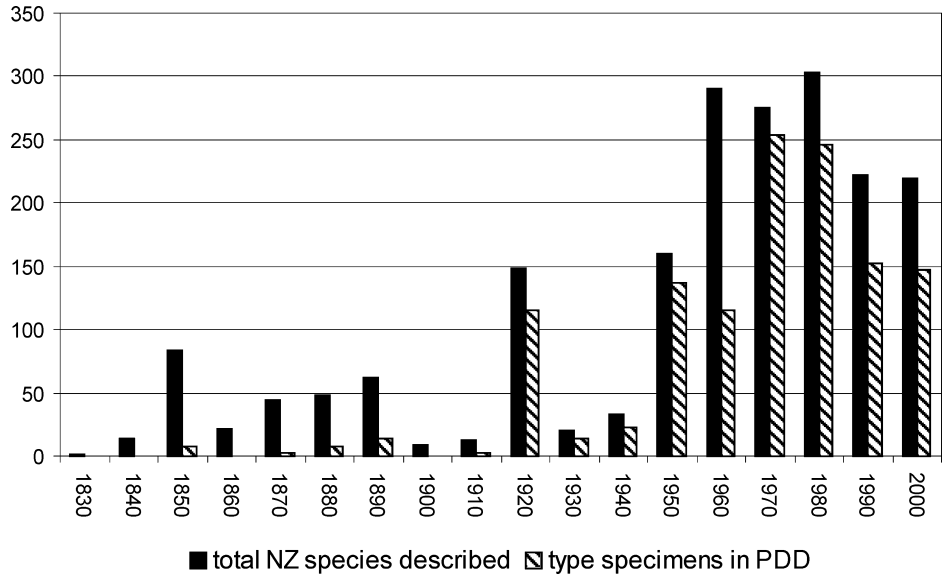

Fig. 5. Number of species described with a New Zealand type specimen for each 10 year period from 1830, and the number of those specimens deposited in the New Zealand Fungal Herbarium (PDD). If not in PDD, almost all of the New Zealand types are in overseas herbaria.

Fig. 6. The collection vault of the New Zealand Fungal Herbarium (PDD). The vault is climate controlled (18°C, RH 50%) and has a gas-flood fire control system. To assist with insect control, all collections are frozen for one week before they are taken into the vault.

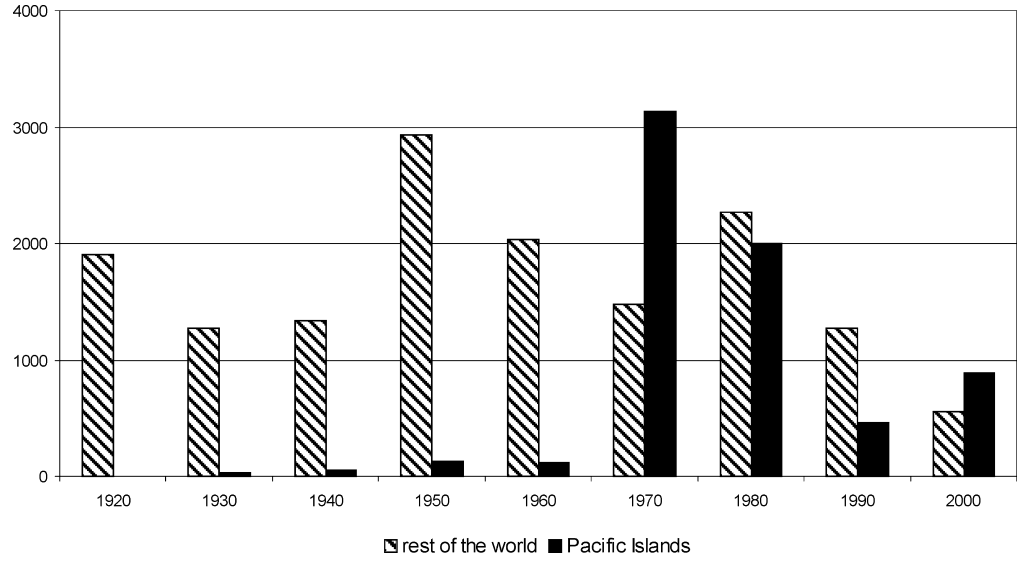

Fig. 7. The number of collections in the New Zealand Fungal Herbarium (PDD) which are not from New Zealand, each 10 year period tallied on the basis of the date of collection. Collections from the Pacific Islands and from the rest of the world are indicated separately.

The New Zealand Fungal Herbarium (PDD)

Herbarium PDD is the largest collection of New Zealand fungi in the world. Attached to several different Government Departments over the years since its establishment in the 1920's, PDD is now maintained by Landcare Research on behalf of the New Zealand Government as a Nationally Significant Collection. It contains over 80,000 collections of fungi, about two-thirds from New Zealand (Fig. 6). Overseas collections include purchased exsiccatae and exchange specimens from Europe and North America, as well as overseas collections made by PDD mycologists. The 1970's and 1980's saw a large increase in specimens collected from the Pacific Islands (Fig. 7). These are mostly voucher specimens supporting disease records for the Pacific Islands, collected as part of ongoing disease surveys carried out by PDD mycologists during that time. They provide the data supporting the subsequent development of plant quarantine regulations for the Pacific Island nations.

Following its establishment by Cunningham in 1920, the New Zealand Fungal Herbarium has undergone two major developments–the addition of a collection of living cultures (the International Collection of Microorganisms from Plant (ICMP) culture collection) and the development of the NZFungi database.

ICMP Culture Collection

The International Collection of Microorganisms from Plants (ICMP) was established in the early 1960's and today contains about 15,000 living cultures, comprising about 6,500 fungi and about 8,500 plant pathogenic bacteria. It is one of the taxonomically most comprehensive collections of plant pathogenic bacteria in the world, with a major proportion of the type strains of the formally described bacterial pathovars. Many of the fungal cultures have been derived from collections now stored as dried specimens in PDD. All cultures are stored as either spore suspensions in freeze-dried ampoules, or more recently in 10% glycerol under liquid nitrogen. A

searchable ICMP catalogue is available over the web (http://nzfungi.landcareresearch.co.nz/icmp/search_cultures.asp).

NZFungi Database

The NZFungi database contains every name used for a fungus in a New Zealand context. It also contains the basionyms of those names, and where there are synonyms, the currently preferred name. The database contains the nomenclatural literature relating to all of those names. It also contains the literature, the PDD collections and the ICMP cultures which support the use of those names in a New Zealand context. Data on the origin of the fungi are provided, whether they are exotic or indigenous, and when indigenous whether endemic or not. Provided for many of the fungi are within-New Zealand distribution maps, copies of published identification keys (together with a few DELTA interactive keys), published descriptions, images, and links to lists maintained by The Ministry of Agriculture and Forestry on organisms of potential threat to New Zealand, and by the Department of Conservation on rare and endangered fungal species for New Zealand. Links are provided to other nomenclatural databases and to Genbank for DNA sequences derived from New Zealand specimens. Descriptions and images are being progressively added, with a concentration on species described from a New Zealand type specimen. All data is freely available over the web (http://nzfungi.landcareresearch.co.nz).

A range of search forms are provided. **Search Names** allows a search for a name (or any part of a name) to retrieve a list of entries that link to the details page for that name, or its current preferred name if it is a synonym. Names which have been used for taxa present in New Zealand are designated by an adjacent fern leaf symbol. On the name details page are the nomenclatural details for the name and all its synonyms, including the authority and place of publication. Some authors of names are prefixed by 'sensu', which implies that the names used by those were incorrectly applied. In earlier times, names of northern temperate fungi were often incorrectly applied to New Zealand collections. Also included within the synonymy are the anamorph/teleomorph connections between asexual and sexual stages. The database contains many names that do not apply to any currently accepted records of New Zealand species. Such names will have few linked attributes and have often not been comprehensively edited.

The **Search Literature** form provides for searches for articles by title, author, fungus, or host species. The result of the search is a list of references. Each of these provides a link to all the fungal names and the host species associated with each of those names, mentioned in the particular article.

The **Search Herbarium** form allows a search of the collections in PDD by PDD number, fungus, host, country, district within New Zealand, substrate, collector, and collector number. The result of the search is a list of PDD herbarium accession numbers. Type collections are highlighted. Each Accession number provides a link to further details relating to that collection, including any images in the database which have been derived from that collection. Web-accessible locality details are restricted to a Crosby area code (Crosby *et al.*, 1998).

The **Search Cultures** form provides access to the data contained in the ICMP culture collection, using a similar set of searchable attributes as the Search herbarium form, and returning a similar result. Cultures derived from New Zealand material are tagged with a fern leaf symbol.

The **Search Hosts** form provides a service to pathologists and biosecurity staff interested in the fungi and bacteria associated with particular plant hosts. Searches can return the bibliography related to that host, the herbarium specimens collected from that host, or the cultures isolated from that host. The results returned from each of these searches are the same as those from

Search Literature, Search Herbarium, and Search Cultures forms, as described above. All plant host names have links through to the New Zealand Plants–Nga Tipu o Aotearoa database (http://nzflora.landcareresearch.co.nz).

Planned database developments include user-specific interfaces, such as the Virtual Mycota (http:/virtualmycota.landcareresearch.co.nz). This interface provides access to the image and descriptive data available in NZFungi through simple pictorial keys. The main NZFungi interface requires knowledge of a name of a fungus to access any of the data about that fungus. Other interfaces, such as one designed to access data of interest to plant pathologists, are also planned.

Also planned is the development of a web interface that allows simultaneous searching of the Forest Research fungal collections database, currently not publicly accessible. Although much smaller than PDD, this is the only other significant local collection of plant-associated fungi. Forest Research collections target especially fungi associated with trees.

DNA Collection

A third new development is being planned for the New Zealand Fungal Herbarium, one that reflects the increasing importance of DNA data to fungal systematics, and the need to anchor that molecular data to well-managed, authentic dried vouchers and cultures. We envisage providing facilities to store extracted DNA alongside the dried specimens and living cultures, so that it is available for use by future researchers. The database will be expanded to store DNA-based data derived from authentic New Zealand collections and cultures.

References

Bougher, N. L., B. A. Fuhrer & E. Horak, 1994. Taxonomy and biogeography of Australian *Rozites* species mycorrhizal with *Nothofagus* and Myrtaceae. *Australian Systematic Botany*, **7**: 353–375.

Buchanan, P. K., R. E. Beever, D. J. Galloway, T. R. Glare, P. R. Johnston, E. H. C. McKenzie, de M. E. Menna, S. R. Pennycook, G. S. Ridley, J. M. B. Smith & S. L. Stephenson, 2005. The fungi of New Zealand–an introduction. *In* Introduction to Fungi of New Zealand. Fungi of New Zealand Vol. 1. Ed. McKenzie, E. H. C. Fungal Diversity Press. Hong Kong. Pp. 1–48.

Coetzee, M. P. A., B. D. Wingfield, P. Bloomer, G. S. Ridley, G. A. Kile & M. J. Wingfield, 2001. Phylogenetic relationships of Australian and New Zealand *Armillaria* species. *Mycologia* **93**: 887–896.

Coetzee, M. P. A., B. D. Wingfield, P. Bloomer, G. S. Ridley & M. J. Wingfield, 2003. Molecular identification and phylogeny of *Armillaria* isolates from South America and Indo-Malaysia. *Mycologia*, **95**: 285–293.

Cooper, A. & R. A. Cooper, 1995. The Oligocene bottleneck and New Zealand biota: genetic record of a past environmental crisis. *Proceedings of the Royal Society*, *London B Biological Sciences*, **261**: 293–302.

Cooper, R. A. & P. R. Millener, 1993. The New Zealand biota: historical background and new research. *Trends in Ecology and Evolution*, **8**: 429–433.

Crosby, T. K., Dugdale, J. S. & J. C. Watt, 1998: Area codes for recording specimen localities in the New Zealand subregion. *New Zealand Journal of Zoology*, **25**: 175–183.

Fuller, R. J. M., P. K. Buchanan & M. Roberts, 2004. Maori knowledge of fungi/Matauranga o Nga Harore. *In* Introduction to Fungi of New Zealand. Fungi of New Zealand Vol. 1. Ed. McKenzie, E. H. C. Fungal Diversity Press. Hong Kong. Pp. 81–118.

Gamundí, I. J., 1991. Review of recent advances in the knowledge of the Cyttariales. *Systema Ascomycetum*, **10**: 69–77.

Hibbett, D. S., 2001. Shiitake mushrooms and molecular clocks: historical biogeography of *Lentinula*. *Journal of Biogeography*, **28**: 231–241.

Hood, I. A., 1989. Armillaria root disease in New Zealand forests. *New Zealand Journal of Forestry Science*, **19**: 180–197.

Horner, I. J., 1985. How serious is the armillaria problem? *New Zealand Kiwifrui*t, **December 1985**: 20.

Johannesson, H. & J. Stenlid, 2003. Molecular markers reveal genetic isolation and phylogeography of the S and F intersterility groups of the wood-decay fungus *Heterobasidion annosum*. *Molecular Phylogenetics and Evolution*, **29**:

94–101.

Johnston, P. R., 1992. Rhytismataceae in New Zealand 6. Checklist of species and hosts, with keys to species on each host genus. *New Zealand Journal of Botany*, **30**: 329–351.

Johnston, P. R., 2004. Data on the origin of New Zealand's fungi. *New Zealand Botanical Society Newsletter*, **77**: 12–14.

Johnston, P. R., P. K. Buchanan, J. Leathwick, & S. Mortimer, 1998. Fungal invaders. *Australasian Mycological Newsletter*, **17**: 48–52.

Johnston, P. R. & I. J. Gamundí, 2000. *Torrendiella* (Ascomycota, Helotiales) on *Nothofagus*. *New Zealand Journal of Botany*, **38**: 493–513.

Johnston, P. R. & I. J. Gamundí, 2002. Distribution of Southern Hemisphere inoperculate discomycetes, the influence of Gondwanaland. *7th International Mycological Congress, Book of Abstracts*: 14.

Johnston, P. R., D. Park, M. A. Dick, S. Ortiz-Garcia & D. S. Gernandt, 2003a. Identifying *pine-inhabiting Lophodermium* species using PCR-RFLP. *New Zealand Journal of Forestry Science*, **33**: 10–24.

Johnston, P. R., I. J. Horner & R. E. Beever, 2003b. *Phytophthora cinnamomi* in New Zealand's indigenous forests. In '*Phytophthora* in Forests and Natural Ecosystems'. 2nd International IUFRO Working Party 7.02.09 Meeting, Albany, W. Australia 30th Sept. - 5th Oct. 2001'. Eds. McComb, J. A.; Hardy, G. E. St. J., & I. C. Tommerup. Perth, Murdoch University Press. Pp. 41–48.

Johnston, P. R. & D. Park, 2005. *Chlorociboria* (Fungi, Helotiales) in New Zealand. *New Zealand Journal of Botany*, **43**: 679–719.

Johnston, P. R., S. R. Pennycook & M. A. Manning, 2005. Taxonomy of fruit rotting fungal pathogens: what's really out there? *New Zealand Plant Protection*, **58**: 42–46.

Knapp, M., K. Stockler, D. Havell, F. Delsuc, F. Sebastini & P. J. Lockhart, 2005. Relaxed molecular clock provides evidence for long-distance dispersal on *Nothofagus* (Southern Beech). *PLOS Biology*, **3 (1)**: e14.

Mata, J. L, R. H. Petersen & K. W. Hughes, 2001. The genus *Lentinula* in the Americas. *Mycologia*, **93**: 1102–1112.

McKenzie, E. H. C., 1983. Mycological history and exploration in New Zealand. *Archives of Natural History*, **11**: 233–247.

McKenzie, E. H. C., 2004. The history of taxonomic mycology in New Zealand. *In* Introduction to Fungi of New Zealand. Fungi of New Zealand Vol. 1. Ed. McKenzie, E. H. C. Fungal Diversity Press. Hong Kong. Pp. 49–80.

McNabb, R. F. R., 1968. The Boletaceae of New Zealand. New Zealand Journal of Botany, **6**: 137–176.

Moyersoen, B., R. E. Beever & F. Martin, 2003. Genetic diversity of *Pisolithus* in New Zealand indicates multiple long-distance dispersal from Australia. *New Phytologist*, **160**: 569–579.

O'Donnell, K., T. J. Ward, D. M. Geiser, H. C. Kistler & T. Aoki, 2004. Genealogical concordance between the mating type locus and seven other nuclear genes supports formal recognition of nine phylogenetically distinct species within the *Fusarium graminearum* clade. *Fungal Genetics and Biology*, **41**: 600–623.

Paulus, B. C., N. Hallenberg, P. K. Buchanan & G. K. Chambers, 2000. A phylogenetic study of the genus *Schizopora* (Basidiomycota) based on its ITS DNA sequences. *Mycological Research*, **104**: 1155–1163.

Petersen, R. H., 1988. The clavarioid fungi of New Zealand. DSIR Bulletin 236. Science Information Publishing Centre, DSIR. Wellington.

Rifai, M. A., 1968. The Australasian Pezizales in the herbarium of the Royal Botanic Gardens Kew. *Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen*, *Afd. Natuurkunde*, *2de Reeks*, **57 (3)**: 1–295.

Stevens, G. R., 1980. New Zealand adrift. A. H. & A. W. Reed. Wellington.

Trewick, S. A. & M. Morgan-Richards, 2005. After the deluge: mitochondrial DNA indicates Miocene radiation and Pliocene adaptation of tree and giant weta (Orthoptera: Anostostomatidae). *Journal of Biogeography*, **32**: 295–309.

Weinstein, R. N., D. H. Pfister & T. Iturriaga, 2002. A phylogenetic study of the genus *Cookeina. Mycologia*, **94**: 673–682.

Wright, S. D., C. G. Yong, J. W. Dawson, D. J. Whittaker & R. C. Gardner, 2000. Riding the ice-age El Nino? Pacific biogeography and evolution of *Metrosideros* subgenus *Metrosideros* (Myrtaceae) inferred from nrDNA. *Proceedings of the National Academy of Science*, **97**: 4118–4123.