

# Re-evaluation of the taxonomic status of *Christella dentata* (Thelypteridaceae) supports recognition of one species in New Zealand

Pat Brownsey\* and Leon Perrie

\*Museum of New Zealand Te Papa Tongarewa, PO Box 467, Wellington, New Zealand  
(patb@tepapa.govt.nz)

**ABSTRACT:** Several publications over the last 30 years have suggested that there may be more than one species of *Christella* in New Zealand: one with creeping rhizomes found in Northland and the Kermadec Islands, referable to the widespread species *C. dentata*; and another of uncertain status with short-creeping or erect rhizomes, confined to thermal regions in the North Island and the Kermadec Islands. The taxonomic status of these plants has been re-evaluated based on collections in the main New Zealand herbaria and field observations from botanists who have collected them. Analysis of frond and rhizome morphology, spore size and cytology indicates that the only difference between the two groups is the nature of the rhizome. Based on current knowledge, we conclude that only one rather variable species, *C. dentata*, is indigenous to New Zealand, and that it shows similar variation to the species in Australia. In addition, there are a few populations naturalised in northern New Zealand, some of which are slightly different in appearance to the indigenous plants and have probably been introduced from overseas sources, and others that may have originated from indigenous plants brought into cultivation.

**KEYWORDS:** *Christella dentata*, Thelypteridaceae, New Zealand flora, taxonomy.

## Introduction

The family Thelypteridaceae was first recognised in New Zealand by Allan (1961), who included all five indigenous species within the broadly construed genus *Thelypteris*. Previously, they had been assigned to various genera within the Polypodiaceae (Hooker 1867; Cheeseman 1906, 1925). Subsequently, Holttum (1971), in the Old World, and Smith (1971), in the New World, revolutionised our understanding of the family, defining many new genera and species in the Thelypteridaceae.

Holttum (1976) recognised *Christella* as a distinct genus with about 50 species, mostly in the Paleotropics but with one species in New Zealand. He distinguished the genus principally by the presence of a thick, elongate, blunt unicellular hair on the stalks of the sporangia (Holttum 1971).

In addition, he noted that the lower pinnae are gradually reduced, the aerophores at the base of the pinnae are not swollen, acicular hairs are usually present on both surfaces of the lamina, short capitate hairs are often present, thick red or orange glandular hairs are sometimes present (but not in New Zealand), sessile spherical glands are absent, the basal veins from adjacent pinnules usually join, and the sori are indusiate (Holttum 1977). Smith (1971) and Smith *et al.* (2006) included *Christella* within a more broadly circumscribed *Cyclosorus*, but recent work suggests that *Christella* is polyphyletic, with most Paleotropical species, including *Christella dentata*, not congeneric with Neotropical species (Almeida *et al.*, 2016). Since clear generic boundaries have not yet been established, Holttum's classification is followed here for consistency within the Australasian and Pacific regions.

Allan (1961) recognised a single species of what we now call *Christella* in New Zealand, making the new combination *Thelypteris dentata* (Forssk.) Allan. Given (1981) was the first to suggest that plants of *Christella dentata* from thermal areas might be different to those from around Kaitaia, which he related to '*C. dentata* of the tropics', but did not elaborate on how the two could be distinguished. Pursuing this idea, Brownsey, Given and Lovis (1985: 441) listed two taxa, *C. dentata* and *C. sp.*, noting 'that two species of *Christella* may occur in New Zealand, one in thermal areas and the Kermadec Islands, and one in North Auckland'. Brownsey & Smith-Dodsworth (1989) further distinguished the thermal plant by its shorter rhizome and smaller fronds (stipes 90–350 mm long, laminae 200–700 mm long and 80–250 mm wide) compared to Northland plants (stipes 200–600 mm long, laminae 300–1000 mm long and 130–400 mm wide), but noted that 'its taxonomic status and affinities are not yet determined'. Davison (1995) investigated *Christella* in New Zealand for an M.Sc. thesis at the University of Auckland, but the results of her work have never been published. de Lange *et al.* (2010: 85) stated that 'Populations of *Christella* from geothermally active parts of the North Island and from the crater region of Raoul Island lack the long, creeping rhizome typical of northern New Zealand and most Raoul Island *C. dentata*, instead producing over time a small, erect trunk. These plants also have narrower, hairier fronds.' They concluded that 'these plants are not the same as *C. dentata*, and appear to represent another possibly unnamed variant' but cautioned that further research was still needed. The status of these two forms is re-evaluated here.

In New Zealand, *Christella dentata sensu lato* extends from the Kermadec Islands to just south of Lake Taupo in the central North Island. It has been recorded in lowland sites on Raoul, Macauley and Cheeseman islands in the Kermadec Islands (Sykes 1977; de Lange 2015a,b). In the far north of the North Island, it is known from Te Pahi (Spirits Bay, Te Huka Bay, Akura Stream and Waitangi Stream), and from a few localities near Awanui north of Kaitaia. It occurs in thermal regions from Rotorua to Tokaanu, and has also been collected from near Kawhia Harbour and from Paemako near Piopio in northern Taranaki. A few populations in Auckland and Hamilton are naturalised. Plants from the Kermadec Islands, Northland and thermal areas of the North Island are all indigenous, but the status of the plants in the western Waikato and north Taranaki is uncertain.

Outside New Zealand, *Christella dentata* is widely distributed in the tropics and subtropics of the Old World, from Africa (Roux 2009) to India, Asia, Australia (Bostock

1998) and most of the islands of the Pacific (Holtum 1977). It extends north to the Azores, Madeira and Crete (Brownsey & Jermy 1973), and the name of the species is based on a type from Yemen (Forsskål 809, C 10002814, Botanical Museum, University of Copenhagen). It is now naturalised throughout the Neotropics (Smith 1971; Holtum 1976) and Hawai'i (Palmer 2003). Strother & Smith (1970) noted that it was a common fern of greenhouses and botanical gardens but was collected in the New World only twice before 1930. It was first recorded in Hawai'i in 1887 but has since spread widely (Palmer 2003).

The species is uniformly tetraploid with  $n = 72$  throughout its range (see Löve *et al.* 1977 for original references). In New Zealand, counts have been obtained from a geothermal population near Taupo ( $n = 72$ , Brownlie 1961, as *Christella nymphalis*) and from Foley's Bush, Awanui, Northland ( $2n = 144$ , de Lange *et al.* 2004). In Australia, four tetraploid counts have been obtained (Tindale & Roy 2002). Based on work by Ghatak & Manton (1971), Holtum (1976) noted that the closely related species *C. hispidula* (Decne.) Holtum is diploid in the Old World, whilst Smith (1971, as *Thelypteris quadrangularis*) showed that it is also diploid in the New World.

The question of whether there are one or two taxa of *Christella* in New Zealand is important because the genus reaches its southernmost limit in northern New Zealand, and plants are rare. *Christella dentata* was given a conservation status of 'At Risk/Naturally Uncommon' by de Lange *et al.* (2013), and further assessment of its status depends on whether it encompasses one or more different species. In preparing the treatment of Thelypteridaceae for the electronic *Flora of New Zealand* (Brownsey & Perrie, submitted), we have re-evaluated the taxonomic status of *C. dentata* in New Zealand. Our observations are presented here and will be summarised in the electronic *Flora* treatment.

## Materials and methods

Over 230 herbarium sheets of *Christella dentata* in the Auckland War Memorial Museum Herbarium (AK), the Allan Herbarium at Landcare Research–Maanaki Whenua (CHR) and the Museum of New Zealand Te Papa Tongarewa Herbarium (WELT) were examined, and collection data noted. Measurements of rhizome, stipe, lamina and pinna dimensions were taken from 50 specimens, and separated, as far as possible, into two groups representing, on one hand, *C. dentata* from Northland and non-crater regions of the Kermadec Islands, and, on the other, the geothermal

Table 1 Range of morphological variation in populations of *Christella dentata* from Northland and non-crater regions of the Kermadec Islands compared to those from thermal areas of the Kermadec Islands and central North Island. Extreme sizes for individual specimens are given parenthetically. For rhizome measurements, reported figures in brackets are taken from collectors' data or field observations rather than from herbarium specimens.

Character	Northland and non-crater Kermadec Is plants (23 specimens)	Thermal area plants (27 specimens)
Rhizome	Creeping to 150 mm long (reported up to 1000 mm long)	Short-creeping to 55 mm long, or erect to 70 mm tall (reported up to 1000 mm tall)
Origin of stipes	Tufted near apex, 2–10 mm apart	Tufted at apex, 1–8 mm apart
Fronde length (mm)	397–980	415–1020 (1195)
Stipe length (mm)	110–350	(75) 120–334
Lamina length (mm)	290–710	242–730 (945)
Lamina width (mm)	110–350	88–215 (275)
Lamina length/width	(1.09) 1.88–3.71	1.95–4.75
No. of pinna pairs	16–40	8–35 (40)
Longest pinna length (mm)	60–155 (240)	45–135 (150)
Longest pinna width (mm)	13–31	10–24
Pinna length/width	3.84–8.16	3.2–7.89
Basal pinna length (mm)	8–60 (89)	5–55 (72)
Pinnule length (mm)	7–15	5–12
Incision length (mm)	2.5–11.5	2.5–8.5
% divided to costa	31–77	35–82

populations from the central North Island and the crater region of Raoul Island, together with one population from Te Pahi. Observations were also made of the hairiness of the plants.

Additional field observations of plants on the Kermadec Islands and in Northland, especially by Peter de Lange and Jeremy Rolfe, are recorded where appropriate.

Measurements of the exospore were made from spores mounted in gum chloral. Twenty spores were measured from each of five populations representing *Christella dentata* from Northland and non-crater regions of the Kermadec Islands, and from geothermal populations.

## Results

The results of the morphological analysis are presented in Table 1, and the comparison of spore size in Table 2.

The results of the morphological analysis (Table 1) show that, apart from the rhizome character, there is substantial overlap in the measurements for different characters from the two groups. Only in stipe length, lamina width, length of the longest pinna and length of the basal pinna are there any substantive differences at all between the two groups. However, the differences are so slight in the context of the overlapping ranges that they could not be used to distinguish separate taxa.

Table 2 Range of variation in spore size in populations of *Christella dentata* from Northland and non-crater regions of the Kermadec Islands compared to those from thermal areas of the Kermadec Islands and central North Island.

Character	Northland and non-crater Kermadec Is plants (5 specimens)	Thermal area plants (5 specimens)
Spore length ( $\mu\text{m}$ )	37.8–42.7	37.8–42.9
Spore width ( $\mu\text{m}$ )	25.3–29.8	26.5–29.5

Of the qualitative characters, the hairiness of the fronds does not appear to vary significantly between the two groups and certainly not in any consistent way that could be used to discriminate them. Quantitative measurement of the degree of hairiness has not been attempted, but simple observation does not suggest any difference between the two groups.

Measurements of spores from five populations of both groups (Table 2) show that their dimensions are virtually identical. Chromosome counts have previously been made from single populations of the two groups of plants (Brownlie 1961; de Lange *et al.* 2004) and both are tetraploid. There is no evidence to indicate that New Zealand plants are anything other than tetraploid.

The only difference between the two groups concerns the nature of the rhizome. Measurements from herbarium specimens show that the Northland and non-crater Kermadec Islands group had creeping rhizomes up to 150 mm long, with the stipes arising 2–10 mm apart (two specimens), whereas those attributed to the thermal group had rhizomes either short-creeping to 55 mm long, with the stipes arising 1–8 mm apart, or erect and up to 70 mm tall (nine specimens). In both groups the stipes were tufted near the apices of the rhizomes. However, because these are rare or threatened plants, very few collections have been made of rhizomes, and herbarium specimens do not necessarily provide an accurate reflection of the plants in the wild. Additional observational data from notes on herbarium specimens, and from personal observations in the field, indicate that the Northland and non-crater Kermadec Island populations sometimes have creeping rhizomes up to 1000 mm long (de Lange 2015c), while plants attributed to the thermal group occasionally produce rhizomes up to 1000 mm tall (Te Huka Bay, Te Pahi, de Lange 9203, AK 314009).

## Discussion

It is clear from the results of the analysis that there is no quantitative frond measurement that could be used to distinguish two separate taxa. This contradicts the descriptions of the fronds of the two groups given by Brownsey & Smith-Dodsworth (1989), who suggested that the thermal plants had shorter stipes, and shorter and narrower laminae. Although Brownsey & Smith-Dodsworth (1989) gave no indication of how many specimens were examined, their measurements were made entirely from material in WELT. It is now apparent that this limited sampling is not supported by examination of a wider and more comprehensive range of specimens.

The analysis of spore size, combined with the previously reported chromosome numbers, strongly suggests that the populations in New Zealand are uniformly tetraploid. This is consistent with results in other parts of the world. In particular, there is no evidence that the morphologically similar diploid species *Christella hispidula* is present in New Zealand. That species is recorded for Australia, where it is said to be 'difficult to distinguish from *C. dentata*' (Bostock 1998), and its occurrence in New Zealand was a possibility that needed to be considered.

A preliminary genetic investigation also found no differences. DNA sequences for the chloroplast *rps4* locus (*rps4* gene and *rps4-trnS* spacer) for a sample from Taupo (Perrie 6263, WELT P027368) were identical to those for a sample from a non-thermal site on the Kermadec Islands (de Lange s.n., AK 307043).

Recognition of two separate groups within indigenous populations of New Zealand *Christella dentata* therefore depends entirely on the rhizome differences. Herbarium specimens and especially observational field data indicate that there are plants with rhizomes that creep up to

1000 mm and that tend to occur in coastal wetlands, along riverbanks and in alluvial forest remnants, and plants with rhizomes that develop over time into a small erect trunk and that occur mostly in geothermally active parts of northern New Zealand (de Lange *et al.* 2010). However, in both groups, the rhizomes are fundamentally similar in that they produce tufts of fronds near the apex, rather than fronds that are widely spread along the rhizome (as in families with long-creeping rhizomes such as Dennstaedtiaceae, Hymenophyllaceae or Polypodiaceae). Similar variation in rhizome behaviour occurs in other ferns, notably *Cyathea dealbata* and *Cyathea colensoi* in New Zealand (Brownsey & Perrie 2015), and *Hypolepis tenuifolia* in the Pacific (Brownsey 1987). Whether the rhizome is prostrate or erect may not be of great taxonomic significance, and may simply be a reflection of different habitats in which the plants are found.

Similar variation has been reported in Australian populations of *Christella dentata*. Bostock (1998: 346–347) described the rhizomes as ‘short-creeping, indistinctly suberect or erect’, and noted that ‘plants vary greatly in size, colour and texture of lamina and pinnae, and slightly in the depth of lobing of the pinnae’. This exactly mirrors the range of variation seen in New Zealand populations.

Without any further evidence to the contrary, we conclude that there is only one rather variable species indigenous to New Zealand, similar to that in Australia, which is correctly identified as *Christella dentata*. However, if further morphological, cytological or genetic differences can be found that correlate with the rhizome character, there may yet be a case for recognising two different taxa.

Some naturalised plants of *Christella dentata* in New Zealand have a slightly different appearance to those that are indigenous, and complicate the picture still further. *Christella dentata* is naturalised in the Neotropics (Smith 1971; Holtum 1976) and in Hawai’i (Palmer 2003). Plants from these areas have distinctive purple stipes that are very similar to those of some naturalised plants in New Zealand (e.g. Seaview Terrace, Mt Albert, Auckland, de Lange 7937 *et al.*, AK 305922, WELT P023359) and to some that are of uncertain status (e.g. near Kawhia, de Lange 1733, AK 212348, WELT P017566). It is likely that some naturalised plants in New Zealand have established as escapes from cultivation, originally introduced from overseas. The earliest record is the plant grown from spore collected near Kawhia by Peter de Lange in 1987 (AK 212348), but other plants have been collected from 1991 onwards. Given the aggressive naturalisation of this plant in

the Americas, it is likely that it will spread in New Zealand unless carefully controlled. A few populations naturalised in Auckland and Hamilton (e.g. Jesmond Terrace, Mt Albert, Auckland, de Lange 7938, AK 305923, WELT P023360) lack the characteristic purple stipes and may have originated from indigenous plants brought into cultivation at various sites nearby.

## Acknowledgements

This research was supported by Core funding for Crown Research Institutes from the Ministry of Business, Innovation and Employment’s Science and Innovation Group. We are especially grateful to Peter de Lange and Jeremy Rolfe for collections, observational data and photographs of *Christella dentata* from Northland and the Kermadec Islands, and to Jessie Prebble for help with DNA sequencing. We also thank staff at the Auckland War Memorial Museum Herbarium (Auckland, New Zealand), the Allan Herbarium at Landcare Research–Maanaki Whenua (Lincoln, New Zealand) and the Museum of New Zealand Te Papa Tongarewa Herbarium (Wellington, New Zealand) for access to collections in their care, and Peter Bostock and Alan Smith for their comments as referees of the manuscript.

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