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Identification and description of feathers in Te Papa's Māori cloaks

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ABSTRACT: For the first time, scientific research was undertaken to identify the feathers to species level contained in 110 cloaks (kākahu) held in the Māori collections of the Museum of New Zealand Te Papa Tongarewa (Te Papa). Methods of feather identification involved a visual comparison of cloak feathers with museum bird specimens and analysis of the microscopic structure of the down of feathers to verify bird order. The feathers of more than 30 species of bird were identified in the cloaks, and consisted of a wide range of native and introduced bird species. This study provides insight into understanding the knowledge and production surrounding the use of materials in the cloaks; it also documents the species of bird and the use of feathers included in the cloaks in Te Papa's collections from a need to have detailed and accurate museum records.

KEYWORDS: Māori feather cloaks, kākahu, cloak weaving, birds, feathers, harakeke, microscopic feather identification, barbule, nodes, New Zealand.

Introduction

The Museum of New Zealand Te Papa Tongarewa (Te Papa) houses more than 300 Māori kākahu (cloaks), of which 110 incorporate feathers. Fully feathered cloaks such as kahu kiwi (kiwi-feather cloaks), kahu kura (kākā-feathered or red cloaks) and kahu huruhuru (feather cloaks) are documented. The remaining cloaks have feathers in the borders or in small bunches, such as in korowai (cloaks that may have hukahuka, or two-ply flax-fibre tassels) and korowai kārure (cloaks with unravelling two- or three-ply flax-fibre tassels) (Fig. 1). Feathers were also identified in kaitaka (finely woven cloaks with tāniko, or colour geometric patterns, along the borders) and pihepihe (cloaks with cylindrical flax tags) (Pendergrast 1987).

The finer Māori cloaks found in Te Papa's collections are generally produced by scraping the leaves of the harakeke (New Zealand flax, *Phormium* spp.), and then weaving the resulting muka (flax fibre) to create the foundation of the cloak (Pendergrast 1997: 6). The single-pair twining method (whatu aho pātahi) was employed for some coarser rain cloaks or capes, whereas the technique of double-pair twining (whatu aho rua) was used to secure attachments such as feathers, and hence was chosen for more decorative cloaks (Pendergrast 1987: 14). The feathers were typically bunched or butted together and woven into the cloak as it was being made. By using the finger twining technique of whatu, the base of the feather shaft is secured to the vertical backing muka warps (whenu) using two pairs of smaller horizontal weft threads (aho rua), and the feather shaft is then bent back on itself to hold it in place (Te Kanawa 1992: 34).

Fragments of a seventeenth-century Māori cloak from a burial site in Strath Taieri in Central Otago were first described by Hamilton (1892: 487) and later discussed by Simmons (1968: 6), who suggested that, judging from the presence of weka (*Gallirallus australis*), albatross (family Diomedeidae) and moa (order Dinornithiformes) skin and feathers sewn and roughly attached to the fragments, the cloak was a prestige item. The find also exemplifies the change of birds and feathers used in Māori cloaks over time, which is seemingly dependent on the materials available, the preferred bird species, and the knowledge, skills and innovation of the weaver at the time of production.

Fig. 1 Korowai kārure (cloak with unravelling flax-fibre tassels) (Te Papa ME014388).

Literature documenting nineteenth- and early twentieth-century Māori feather cloaks mentions primarily the following endemic New Zealand species: brown kiwi (*Apteryx* spp.), New Zealand pigeon (kererū, *Hemiphaga novaeseelandiae*), kākā (New Zealand bush parrot, *Nestor meridionalis*), parakeet (kākāriki, *Cyanoramphus* spp.) and kākāpō (night parrot, *Strigops habroptilus*) (Hiroa 1911: 84). Feathers from weka and the now extinct hūia (*Heteralocha acutirostris*) have also been used in kākahu (Te Kanawa 1992: 25). From the latter half of the nineteenth century onwards, striking geometric designs incorporating feathers from newly introduced exotic birds such as peafowl (*Pavo cristatus*), helmeted guinea fowl (*Numida meleagris*) and, later, pheasant (*Phasianus colchicus*) and domestic chicken (*Gallus gallus* var. *domesticus*) (Pendergrast 1987: 107) were sometimes mixed with feathers from declining native bird species.

Since the foundation of the Colonial Museum in 1865, Te Papa's cloak collection has grown, through gifts, loans, donations and acquisitions. Much of the information regarding the origins and materials used in these items was either not obtained or has been lost before their inclusion in the collection. In addition, the origin of feathers used in a large number of cloaks has remained scientifically unverified until now. Various publications on Māori cloaks and bird lore indicate that at least 27 native and eight introduced bird species were used in kākahu after 1800. It is currently accepted that all of the cloaks with feathers studied were produced post 1800. The study and description of microscopic features of feathers from New Zealand birds and a comparison of cloak feathers against identified museum bird skins have facilitated the identification and verification of the bird species used in Te Papa's Māori cloaks for the museum's permanent records. It also enhances our knowledge of the avifauna utilised by Māori, as well as how this has changed with the protection of native bird species, and introduction of American and European game birds.

The identification of feathers from microscopic structures in the down was established by American scientists like Chandler (1916), who studied feather structure and its taxonomic significance among birds. Day (1966) examined feathers and hair microscopically from the gut contents of stoats in the British Isles to identify prey remains. More

recently, scientists from the Smithsonian Institution have used downy structures of feathers and comparisons with museum bird skins to identify feather remains resulting from US Air Force bird strikes (Laybourne & Dove 1994). Microscopic analysis of feathers has also been used to identify birds in textiles from international anthropological and archaeological studies (Dove & Peurach 2002; Rogers *et al.* 2002; Dove *et al.* 2005). It has also been applied successfully in museum collections to infer the possible provenance (or geographic origins) of collection items (Dove 1998; Pearlstein 2010). Dove & Koch (2010) have described the key diagnostic features of feathers for the major bird groups occurring in forensic ornithology.

Microscopic feather identification in New Zealand is still in its infancy. At the date of publication there is no national microscopic reference database of the features that characterise the feathers of New Zealand bird species. Fast alternative methods requiring less accuracy have been used over microscopic identification – such as studying reference collections of feathers to identify New Zealand falcon (*Falco novaeseelandiae*) prey remains (Seaton *et al.* 2008). A national molecular database of some New Zealand birds has assisted in the identification of birds from their DNA for historical and conservation purposes (Shepherd & Lambert 2008; Seabrook-Davison *et al.* 2009), and the identification of emu (*Dromaius novaehollandiae*) feathers in a rare Māori cloak (Hartnup *et al.* 2009).

Microscopic analyses and DNA profiling have been employed successfully to determine the origin of feathers in ethnological collections in overseas studies. Isotopic analysis of feathers, a science new to New Zealand, has also proven effective, with isotope mapping tools used to geo-locate bird origins in international research (Hobson *et al.* 2007). These scientific methods have varying degrees of accuracy and present conservation issues relating to the extraction of materials for analysis.

Materials, methods and conventions

In Te Papa's Māori collections, 110 feathered cloaks were examined using microscopic feather analysis and comparisons with museum bird skins. Feathers from at least 24 native and introduced birds, including species and subspecies, were identified in the cloaks (Table 1). Where possible, bird species were identified with accuracy by comparing whole cloak feathers against museum bird skins. For cloak feathers with little or no morphological characters (i.e. white, black or brown feathers), and feathers that required verification, the bird groups they belong to were identified by comparing diagnostic microscopic structures. Finally, a combination of the two techniques – microscopic characters to determine the bird order and whole-feather identification from museum skins to identify the species/subspecies – were used. It was estimated that for each cloak the number of bird species from which feathers were obtained ranged between one and eight, with an average of three different bird species per cloak. The number of species, as well as the number of individual birds used, depended on the size of the birds, the types of feathers used, the number of feathers butted or bunched together, and ultimately the size and design of the cloak.

A list of potential bird species was prepared, and a database of feather images was created from museum skins, including species names, sex, age and colour variations (see Fig.2). Owing to the size and fragility of the cloak and bird skin collections, and their location in separate buildings, it was logistically more suitable to use an image database to compare cloak feathers with birdskin images. This is contrary to other methodologies utilised by the Smithsonian Institution, where direct comparison of unknown feathers with the skins themselves is preferred.

Detached feathers from bird skins were collected, and the species and feather types recorded to create a reference database of microscopic images of the feather down, and to compare them with fallen cloak feathers. Detached cloak feathers that had been collected and bagged over time (a common museum practice) were used for microscopic identification of some cloaks. These feathers were checked and verified that they had originated from the corresponding cloak based on their size, colour and pattern, if applicable.

Identification methods utilising museum skins and microscopic feather analyses were favoured over other techniques owing to the accuracy required, and the time and monetary restrictions in identifying such a large number of cloaks. These techniques were also preferred as they did not involve any destruction of the collection items.

Downy barbs extracted from contour feathers of a verified museum skin were dry-mounted onto glass slides, and examined using light microscopy (Leica DM500 at 40x, 100x and then 400x magnifications). Images were captured using a fitted microscope camera (Leica ICC50), and the Leica LAS EZ program was employed for processing images and recording measurements. Similarly, detached cloak feathers

Table 1 Native and introduced (*) bird species/subspecies identified in Te Papa's Māori cloak collection, by numbers of cloaks with at least one feather of the listed species. (Total number of cloaks = 110)

Bird species	Number of cloaks with listed species
Brown kiwi – *Apteryx* spp.[A]	52
New Zealand pigeon, kererū – *Hemiphaga novaeseelandiae* (Gmelin, 1789)	45
Kākā, bush parrot – *Nestor meridionalis* (Gmelin, 1788)[B]	43
Tūī, parson bird – *Prosthemadera novaeseelandiae novaeseelandiae* (Gmelin, 1788)	35
Domestic chicken, heihei – *Gallus gallus* var. *domesticus* (Linnaeus, 1758)*	25
Common pheasant, peihana – ♂ *Phasianus colchicus* (Linnaeus, 1758)*	15
Peafowl (peacock) – ♂ *Pavo cristatus* (Linnaeus, 1758)*	13
Weka, woodhen – *Gallirallus australis* (Sparrman, 1786)[C]	12
Pūkeko, swamphen – *Porphyrio melanotus melanotus* (Temminck, 1820)	11
Parakeet, kākāriki – *Cyanoramphus* spp.[D]	10
Wild turkey – *Meleagris gallopavo* (Linnaeus, 1758)*	5
Albatross, toroa – family Diomedeidae[E]	4
Mallard – *Anas platyrhynchos platyrhynchos* (Linnaeus, 1758)*[F]	4
Banded rail – *Gallirallus philippensis* (Linnaeus, 1766)	2
Long-tailed cuckoo, koekoeā – *Eudynamys taitensis* (Sparrman, 1787)	2
California quail – *Callipepla californica* (Shaw, 1798)*	2
Helmeted guineafowl – *Numida meleagris* (Linnaeus, 1758)*	2
Hūia – *Heteralocha acutirostris* (Gould, 1837)	2
Australasian bittern, matuku – *Botaurus poiciloptilus* (Wagler, 1827)	1
Kākāpō, night parrot – *Strigops habroptilus* (G.R. Gray, 1845)	1
Morepork, ruru – *Ninox novaeseelandiae novaeseelanidae* (Gmelin, 1788)	1
Swamp harrier, kāhu – *Circus approximans* (Peale, 1848)	1
Shining bronze-cuckoo, pīpīwharauroa – *Chrysococcyx lucidus* (Gmelin, 1788)	1
Yellowhammer – *Emberiza citrinella* (Linnaeus, 1758)*	1

A North Island, Okarito, South Island and Stewart Island brown kiwi are included.

B North Island kākā and South Island kākā are included.

C North Island, western, buff and Stewart Island weka are included.

D Red-crowned, yellow-crowned and orange-fronted parakeets are included.

E All albatross species of the genera *Diomedea* and *Thalassarche* are included.

F All varieties that interbreed with *Anas superciliosa* are included.

Fig. 2 Feather types from bird skins from Te Papa's collection used in comparisons with whole cloak feathers: (a) belly feathers from an albino North Island brown kiwi; (b) rump feathers from a common pheasant; (c) underwing covert feathers from a North Island kākā; (d) back feathers from a kākāpō; (e) vent feathers from a long-tailed cuckoo; (f) throat tufts from a tūī.

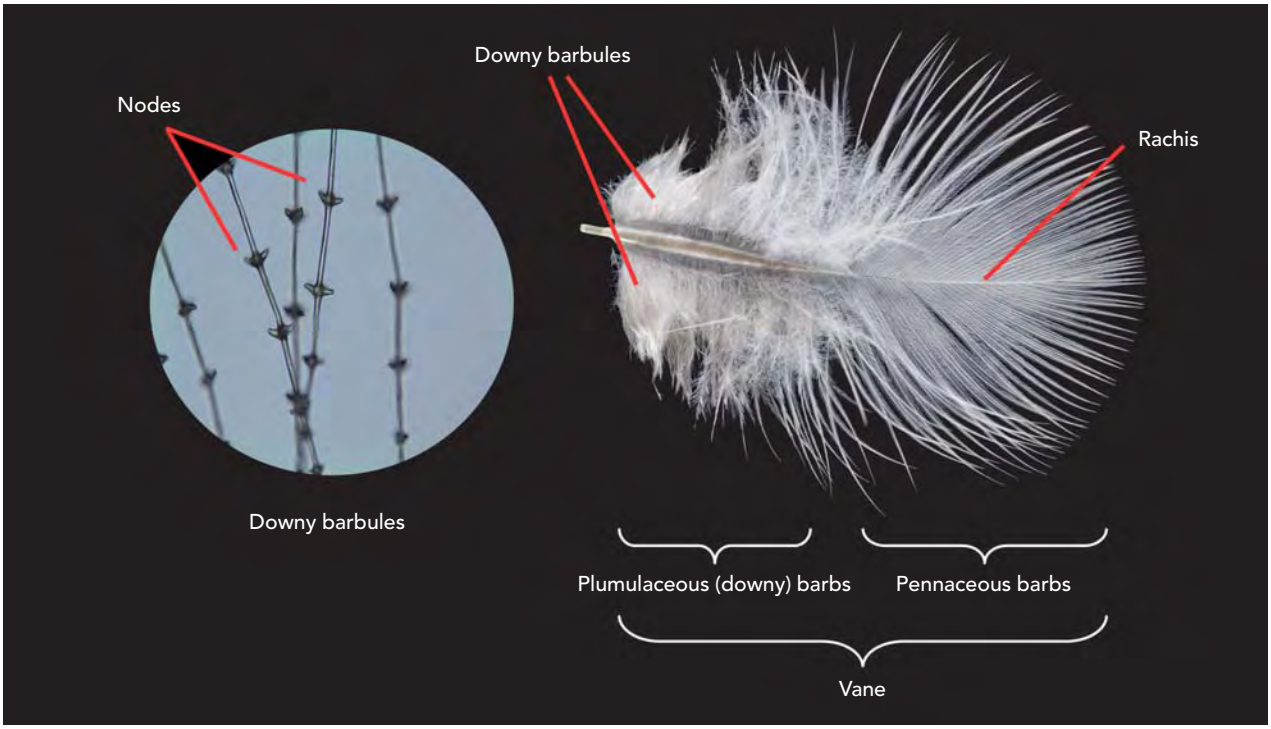

Fig. 3 New Zealand pigeon contour feather, showing pennaceous and plumulaceous (downy) barbs, and the nodes on downy barbules (photo: Raymond Coory).

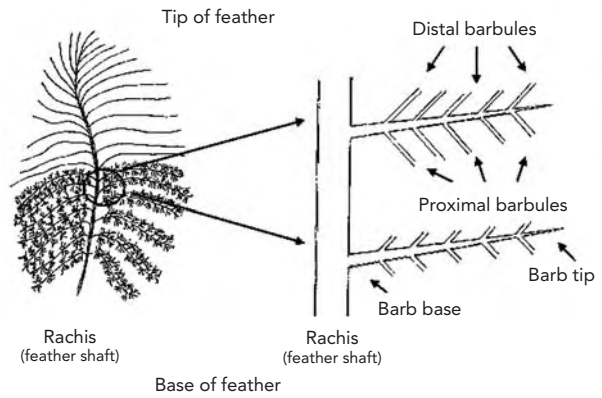

Fig. 4 Diagrammatic structure of a down feather, showing the orientation of barbules on barbs (modified from Day (1966) and Dove & Koch (2010)).

were dry-mounted for microscopic analysis of their nodes, to place the feather within a bird order and, if possible, to identify the bird family or species/subspecies.

Contour feathers from adult skin specimens used for microscopic identification are described as feathers with 'fluffy' down at the base of the feather, a distinct central shaft or rachis, and vanes (barbs) on either side, covering the body of the bird (Marchant & Higgins 1990: 38; Dove 1997: 47) (Figs 3 and 4). Contour feathers can also be found in the wings and tail. The barbs at the tip of the feather are known as pennaceous barbs and have small hooklets that link together, providing structure to the feather. The downy structures at the base of the feather, the plumulaceous barbs, have perpendicular barbules attached (Dove & Koch 2010: 21), which provide insulation for the bird.

Most downy barbules have generally distinctive structures called nodes and/or prongs (see Figs 5–8). The length of the space between two nodes is measured as the internodal length (Dove 1997: 51). The average length and width of the downy barbules vary depending on the bird order. Additional parameters useful in systematic studies of feathers are size/shape, and, sometimes, the distribution of nodes along the barbules. Pigmentation within the nodes and along the barbules is also variable among birds. These microscopic features were observed and recorded for each feather that was not identifiable by direct comparisons with museum skins.

Each feather sample was studied for nodal morphology, pigmentation patterns, length of barbules, presence of villi (transparent fringe-like projections on the base of barbules; Fig. 8e) and other diagnostic characters (e.g. rings, triangle-shaped nodes) that would allow identification of the group

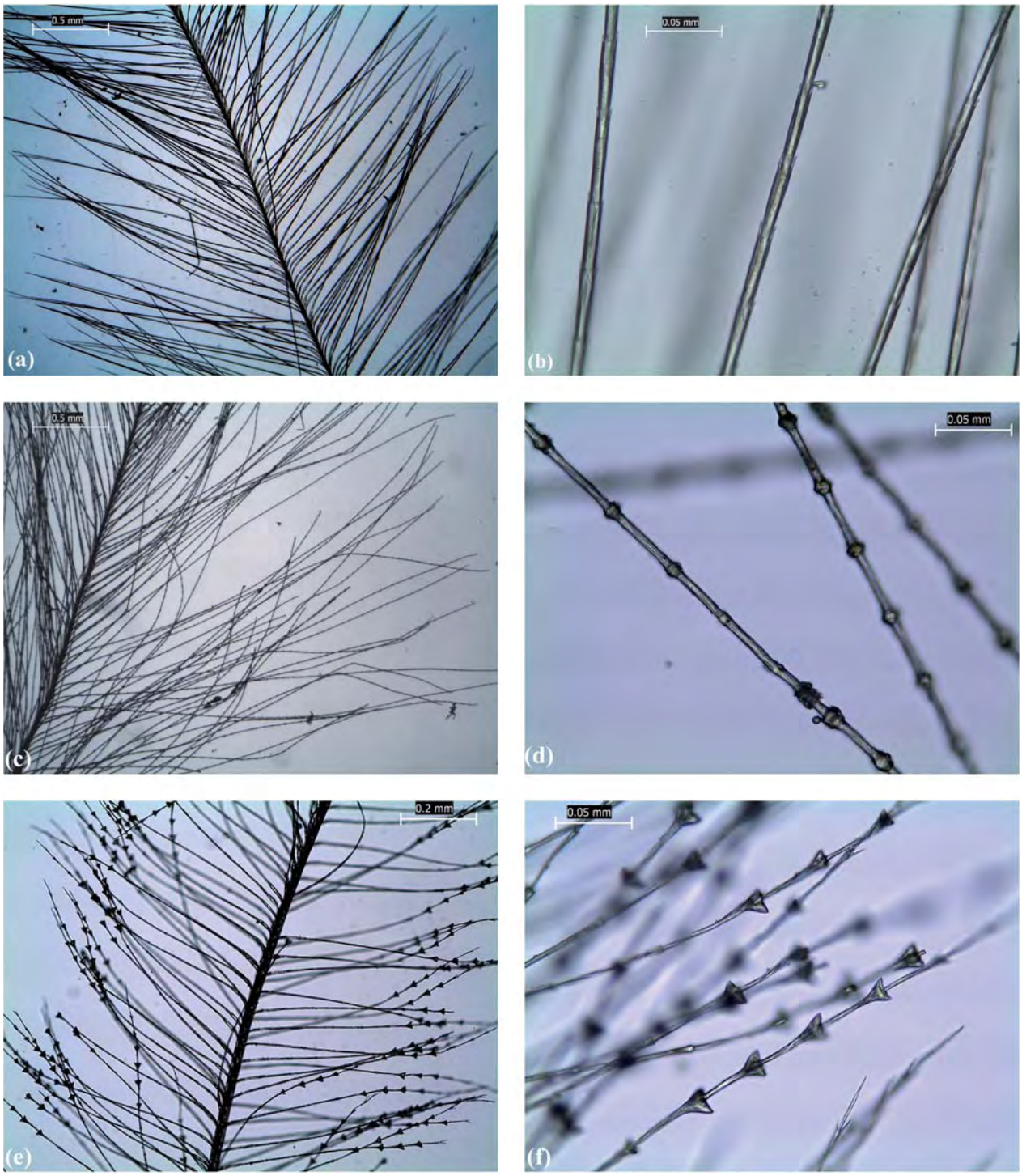

Fig. 5 Photomicrographs of downy barbules from New Zealand birds examined: (a) barbules from a North Island brown kiwi – Casuariiformes; (b) pronged nodes from a North Island brown kiwi – Casuariiformes; (c) barbules from a domestic chicken – Galliformes; (d) multiple ringed nodes from a domestic chicken – Galliformes; (e) barbules from a mallard – Anseriformes; (f) triangular nodes at the barbule tip from a mallard – Anseriformes.

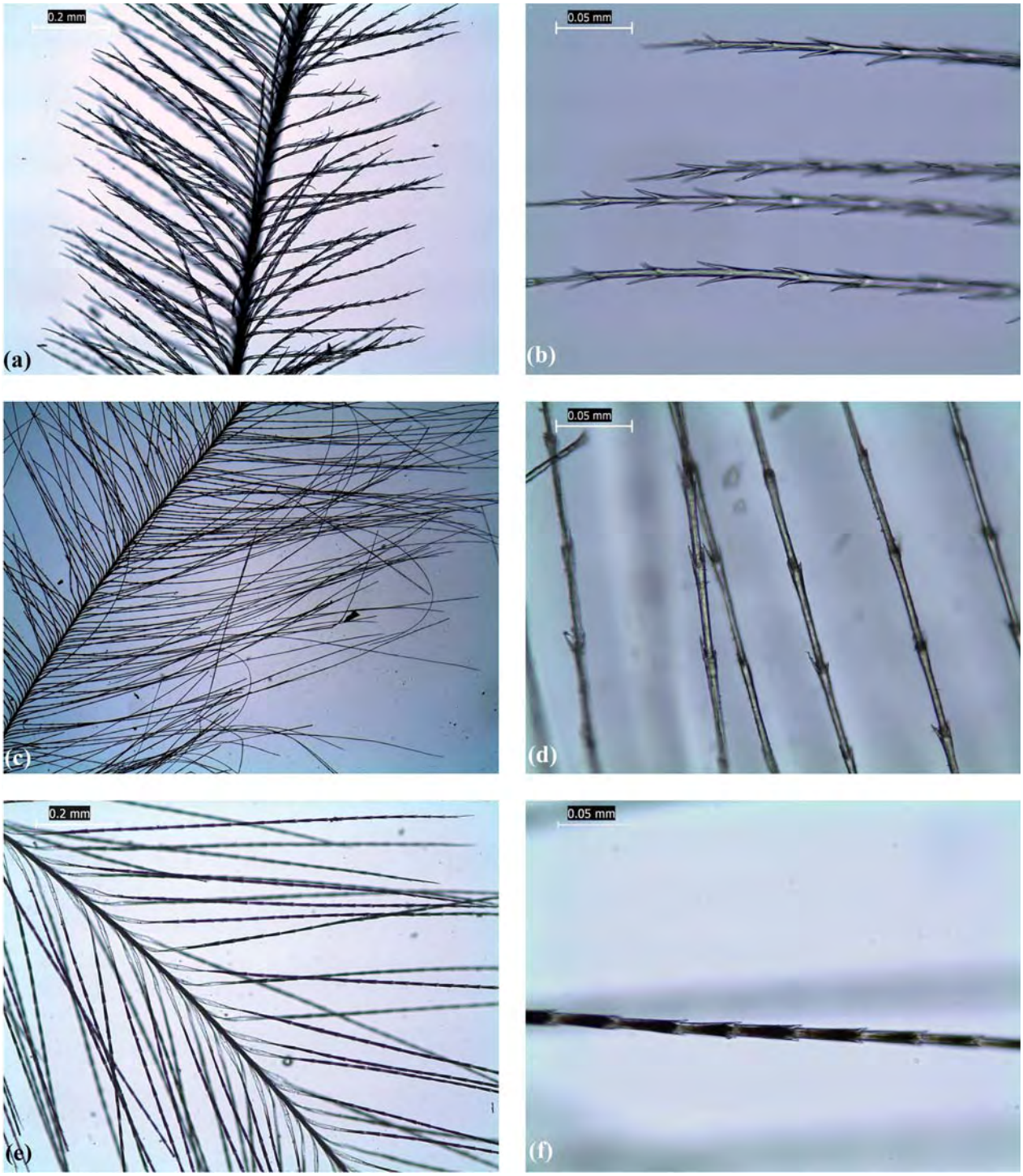

Fig. 6 Photomicrographs of downy barbules from New Zealand birds examined: (a) barbules from a Gibson's albatross – Procellariiformes; (b) pronged nodes from a Gibson's albatross – Procellariiformes; (c) barbules from a swamp harrier – Accipitriformes (40x); (d) asymmetric spined nodes from a swamp harrier – Accipitriformes; (e) barbules from a weka – Gruiformes; (f) internodal pigmentation from a weka – Gruiformes.

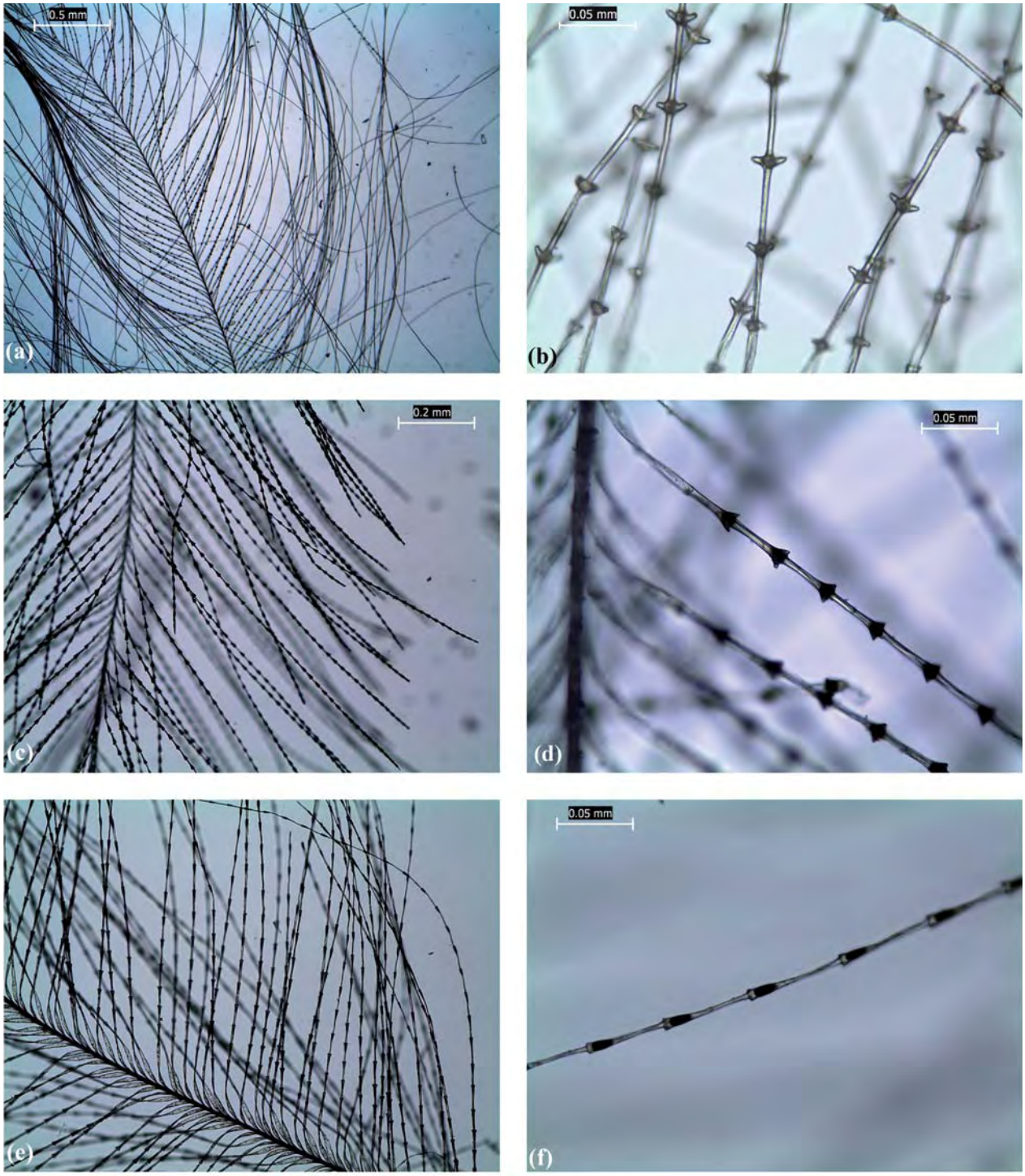

Fig. 7 Photomicrographs of downy barbules from New Zealand birds examined: (a) barbules from a New Zealand pigeon – Columbiformes; (b) crocus-shaped nodes at the barbule base from a New Zealand pigeon – Columbiformes; (c) barbules from a red-crowned parakeet – Psittaciformes; (d) expanded nodes at the barbule base from a red-crowned parakeet – Psittaciformes; (e) barbules from a long-tailed cuckoo – Cuculiformes (100x); (f) pre-nodal pigmented nodes from a long-tailed cuckoo – Cuculiformes.

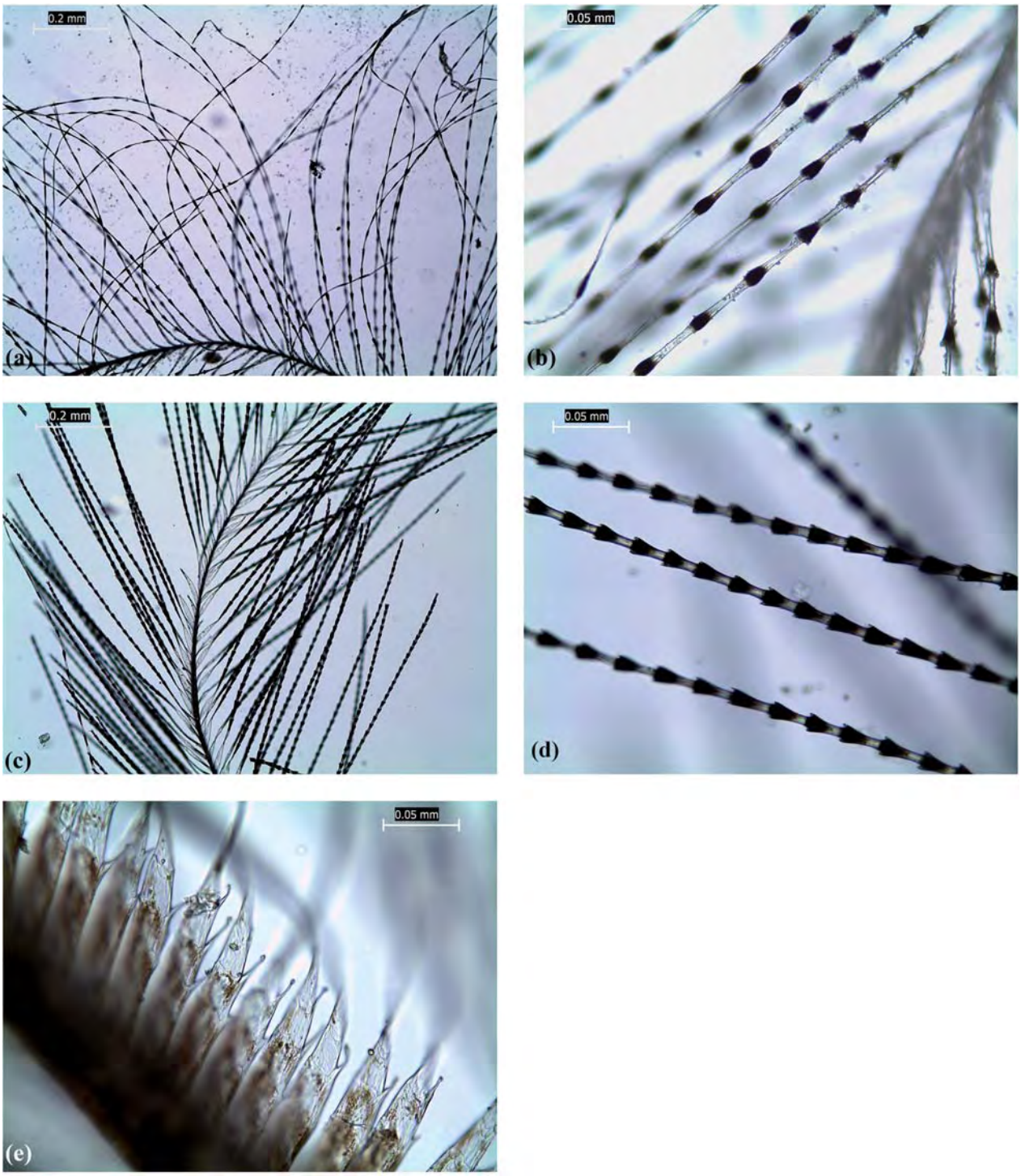

Fig. 8 Photomicrographs of downy barbules from New Zealand birds examined: (a) barbules from a morepork – Strigiformes; (b) large pigmented nodes at the barbule base from a morepork – Strigiformes; (c) barbules from a hūia – Passeriformes; (d) closely spaced pigmented nodes from a hūia – Passeriformes; (e) villi at the barbule base from a hūia – Passeriformes.

of birds to which it belonged (Dove & Koch 2010: 21). As diagnostic features for bird orders may vary among species, feather types, and even between barbs and barbules on a feather, it was important to take several samples, and to use whole feathers for microscopic and museum skin comparisons where possible.

Methods and conventions for the identification of feathers in Te Papa's Māori cloaks follow those described by Chandler (1916) and Day (1966), while descriptions of nodes and pigmentation follow Dove & Koch (2010). Descriptions of feather colour follow Svensson (1992), and descriptions of feather type follow diagrams from Marchant & Higgins (1990). Bird nomenclature, vernacular names and sequence of orders for New Zealand birds follow the *Checklist of the Birds of New Zealand* (Gill *et al.* 2010).

Microscopic feather descriptions and their use in cloaks

There are 21 bird orders present in New Zealand (Gill *et al.* 2010). Feathers from 12 bird orders were identified in Te Papa's cloaks, and the use of species from each order is discussed below. Feathers from 11 bird orders were examined and identified microscopically; key diagnostic features of 16 feathers belonging to 16 bird species/subspecies from those 11 bird orders are summarised in Table 2. The use of different feather types is discussed with respect to their presence in Te Papa's Māori cloaks only. Similar feather types from museum skin species and those recorded in the cloaks have been microscopically examined. This is an initial attempt to describe the feathers of New Zealand bird orders at a microscopic level, and to document diagnostic feather characteristics for replication in future identification research.

Order Casuariiformes, family Apterygidae – kiwi

Kiwi are part of a group of birds known as ratites, which includes emus, cassowaries and moa. Kiwi belong to the family Apterygidae and comprise five species, three species of brown kiwi (including two subspecies) and two species of spotted kiwi (Gill *et al.* 2010: 19). It is inferred that feathers from the North Island brown kiwi (*Apteryx mantelli*) and South Island brown kiwi (*A. australis australis*) are present throughout the cloak collection. However, it was not possible to identify accurately the feathers of brown kiwi to species level using microscopy and comparisons with museum skins alone. A feather from a North Island brown kiwi was microscopically examined to represent this group of birds, and to determine general features of brown kiwi feathers for cloak identifications. Diagnostic characteristics unique to this order are given in Table 2.

Kiwi feathers are hair-like and the barbs are long and filamentous. Chandler (1916: 293) described the microscopic features of feathers from a great spotted kiwi (*Apteryx haastii*) as having some downy barbs at the base of the feather, with small but distinct nodes and prongs present on barbules. Barbules were measured at 2–3 mm long in well-developed downy regions (Chandler 1916: 294). The microscopic examination of *A. mantelli* for this research confirmed similar characteristics within the family Apterygidae. The barbules are medium to long, transparent and flat at the base, tapering to thin and spindly (hair-like) at the tip (Fig. 5a). Nodes are minute and flat, sometimes with four short, symmetrical prongs that point towards the tip of the barbule (Fig. 5b). The tips of some barbules also have large prongs.

Brown kiwi feathers were identified in 52 of Te Papa's cloaks, with feathers fully covering the cloak (kahu kiwi) or applied in strips or small bunches. Kiwi feathers from the body of the bird, roughly uniform in size and colour, were recorded, with the larger, strongly coloured back feathers being more prevalent. Hiroa (1911: 84) also noted the preference of back feathers for kākahu. Most of Te Papa's kahu kiwi are woven to show the ventral side of the feather facing outwards, referred to as whakaarara by Hiroa (1911: 84), but five cloaks have feathers placed as on the bird, referred to as tāmoe by Hiroa (1911: 84). The calamus, or quill, at the very base of the feather is generally woven into the cloak using the muka aho (weft threads). In three cloaks, the tip of a single feather was woven into the cloak with the calamus pointing outwards.

Natural kiwi feather colours in the cloak collection range from white (albino), faded cream or off-white, to light brown, medium brown, rufous (reddish brown), dark brown and black-brown. Pure white (albino) brown kiwi feathers are defined as lacking any kind of pigmentation in the shaft, barbs or barbules (Fig. 2a). Albino feathers were recorded in seven cloaks, observed in patterns as strips, or as single feathers among other brown feathers (Fig. 9). Albino kiwi birds were present but rare in pre-1900 brown kiwi populations, and white kiwi feathers would have been highly coveted by Māori for their inclusion in kākahu. Albinism in kiwi ranged from single feathers to patches of white feathers

Table 2 Summary of microscopic examination of bird feathers identified in Te Papa's Māori cloaks.

Order, family and species/subspecies of bird feather specimens	Feather type and down description	Diagnostic features of feather	Pigment and node distribution on barbules
Order Casuariiformes Family Apterygidae North Island brown kiwi – *Apteryx mantelli* (Bartlett, 1852)	Brown back feathers. Barb sample from middle of down. Barbs are long to very long.	Barbules are medium to long and hair-like (Fig.5a). Minute but distinct nodes with four small symmetrical prongs all along barbules that decrease in size (Fig.5b). Longer prongs at barbule tip.	Little or no pigment in nodes and barbules. Nodes flat with small prongs all along barbules, these becoming thinner and fewer towards barbule tips.
Order Galliformes Family Phasianidae Domestic chicken – *Gallus gallus* var. *domesticus* (Linnaeus, 1758)	Black and white barred belly feather. Barbs are long, fine and dense. Barb sample from middle of down.	Barbules are long (Fig.5c). Multiple ring-like structures surround nodes in middle of barbules, in barbules at base of barbs only (Fig.5d).	Little pigment in barbules and little to medium in nodes. Expanded nodes at barb base. In middle of barbules, bases of nodes detach and form multiple ring-like nodes.
Order Galliformes Family Phasianidae Common pheasant – *Phasianus colchicus* (Linnaeus, 1758)	Brown belly feathers. Down is fine and grey, and dense. Barb sample from middle of down.	Barbules are longer and thinner than in Gallus feather specimen. Considerably fewer multiple ring-like nodes compared with Gallus.	Medium pigment in barbules, with little to medium in nodes. Nodes are all along barbules, and are globular, or expanded with few multiple ring-like nodes.
Order Anseriformes Family Anatidae Mallard – *Anas platyrhynchos platyrhynchos* (Linnaeus, 1758)	Brown and white speckled belly feather. Barb sample from base of feather.	Barbules are short, thread-like and thin (Fig.5e). Two to four distinctive large triangular nodes are located at barbule tips only, in barbules at base of barbs (Fig.5f).	Very tips of barbules have large prongs. Barbules from mid-barb to tip have prongs only from middle of barbule. Little or no pigment in barbules, nodes and prongs.
Order Procellariiformes Family Diomedeidae Gibson's albatross – *Diomedea antipodensis gibsoni* (Robertson & Warham, 1992)	White underwing covert feather. Down is dense. Barb sample from middle of down.	Barbules are very short but slightly increase in length from barb base to tip (Fig.6a). Four symmetrical transparent prongs at each interval along most barbules (Fig.6b).	Little pigment in barbules or prongs. Two to four prongs at each interval, symmetrical in pairs. Prongs slightly curved outwards towards tip, decreasing in size from barbule base to tip.
Order Accipitriformes Family Accipitridae Swamp harrier – *Circus approximans* (Peale, 1848)	Cream belly feather with brown line down shaft. Barb sample from middle of down.	Barbules are long (Fig.6c). Two pairs of asymmetrical pronged nodes at intervals at base and tips of barbule (Fig.6d). Middle of barbules has small prongless nodes.	Barbules have little pigment. Nodes with light to medium pigmentation, small and bulbous, decreasing in size along barbules. Pronged nodes are closely spaced at barbule base and tip.
Order Gruiformes Family Rallidae Western weka – *Gallirallus australis australis* (Sparrman, 1786)	Dark brown flank feather with medium brown mottling. White barb sample from middle of down.	Barbules are dark brown, straight and medium length (Fig.6e). Nodes are indistinct. Small transparent prongs at node intervals, pigment is lacking around prongs (Fig.6f).	Barbules are heavily pigmented and wide. Prong length is uniformly short all along barbules. Internodal spaces are uniform except at tips, where nodes are closely spaced.
Order Gruiformes Family Rallidae Pūkeko – *Porphyrio melanotus melanotus* (Temminck, 1820)	Iridescent black back feather. Barbs are long and white. Barb sample from middle of down.	Barbules are grey and short to medium in length. Barbules have four expanded nodes at base of distal barbules at base of barbs.	Barbules are thin, with medium to heavy pigmentation except around nodes.

Order, family and species/subspecies of bird feather specimens	Feather type and down description	Diagnostic features of feather	Pigment and node distribution on barbules
Order Columbiformes Family Columbidae New Zealand pigeon – *Hemiphaga novaeseelandiae* (Gmelin, 1789)	White belly feather. Down is white and dense. Barb sample from base of feather.	Barbules are long and 'wispy', tapering to very thin at tips (Fig.7a). Four to six expanded crocus-shaped nodes at base of barbules (Fig.7b).	Barbules and nodes have little pigment. Quadrilobed crocus-shaped nodes at barbule base only, then they abruptly decrease in size towards barbule tips.
Order Psittaciformes Family Strigopidae North Island kākā – *Nestor meridionalis septentrionalis* (Lorenz, 1896)	Red-tipped belly feather. Down is grey and white. Barb sample from middle of down.	Barbules are long to very long, with shorter barbules at barb tip. Expanded nodes occur at medium intervals, larger at barb base, globular at mid-barb, and with small prongs at barb tip.	Barbules have little to medium pigmentation and nodes medium to heavy pigmentation, except in node extremities. Pigmented nodes present along barbules become closer and thinner towards barbule tip.
Order Psittaciformes Family Psittacidae Red-crowned parakeet – *Cyanoramphus novaezelandiae novaezelandiae* (Sparrman, 1787)	Light green breast feather. Down is dense. Barb sample from middle of down.	Barbules are medium to long, decreasing in length towards barb tip (Fig.7c). Expanded pigmented nodes at base of barbule (Fig.7d), smaller nodes at medium intervals along remainder. Nodes can have small transparent extremities.	Nodes are pigmented except in lobes. Nodes become longer and thinner towards barbule tip, and some have prongs.
Order Cuculiformes Family Cuculidae Long-tailed cuckoo – *Eudynamys taitensis* (Sparrman, 1787)	White belly feather with a brown line down shaft. Down is dense and grey. Barb sample from middle of down.	Barbs are short and barbules are medium to long in length (Fig.7e). At base of barbules are long, thin, bell-shaped nodes with pre-nodal pigmentation (Fig.7f).	Pigment limited to top of nodes in barbules at middle and base of barb. Nodes decrease in size at base and mid-barb. Nodes at barbule tip are very thin, long and closely spaced.
Order Strigiformes Family Strigidae Morepork – *Ninox novaeseelandiae novaeseelandiae* (Gmelin, 1788)	Brown, cream and white mottled belly feather. Down is soft and dense. Barb sample from base of feather.	Barbs are long, and barbules are medium to long (Fig.8a). Dark, expanded nodes occur at medium intervals at barbule base (Fig.8b), globular nodes at mid-barbule, and thin, long nodes at tip.	Large pigmented triangular nodes at barbule base, with a gradual decrease to smaller nodes at middle, and very thin nodes at barbule tips, these with some prongs.
Order Passeriformes Family Meliphagidae Tūī – *Prosthemadera novaeseelandiae novaeseelandiae* (Gmelin, 1788)	Iridescent black breast feather. Down is grey. Barb sample from middle of down.	Barbules are medium to long. Nodes are heavily pigmented and quadrilobed, with small prongs. Villi are present at base of barb and barbules.	Barbules are wide, pigmented only at nodes. Internodal spaces are short, becoming very short at barbule tip. Nodes are present all along barbules, gradually decreasing in size along barbule.
Order Passeriformes Family Callaeidae Hūia – *Heteralocha acutirostris* (Gould, 1837)	Black breast feather. Down is dense. Barb sample from base of feather.	Barbules are short to medium in length (Fig.8c). Nodes are heavily pigmented and quadrilobed, with short internodal spaces (Fig.8d). Villi with distinctive knobbed ends occur at base of proximal barbules (Fig.8e).	Barbules are wide, width gradually decreases along barbule. Heavy pigment in nodes except in prongs, little to medium pigment in internodal spaces. Nodes triangular, gradually decreasing in size at barbule tip.
Order Passeriformes Family Emberizidae Yellowhammer – *Emberiza citrinella* (Linnaeus, 1758)	Canary-yellow flank feather. Down is dense. Barb sample from middle of down.	Barbules are short to medium length. Nodes are pigmented and quadrilobed, with rudimentary prongs at base of barbules. There are few villi at base of barbules.	Little to medium pigmentation in barbules, heavy in nodes. Internodal spaces of medium length, shorter towards barbule tips.

Fig. 9 Close-up of albino brown kiwi feathers in a kahu kiwi (kiwi-feather cloak) (Te Papa ME002701).

amongst brown feathers (partial albinism), and to pure or full albinism (Buller 1873: 310, 322).

For Māori, kahu kiwi represent mana (status and prestige). They are the most common type of feathered cloak in Te Papa's collections. At least five different kahu kiwi have hidden feathers from other birds, including hūia, kākā, and weka, which can be viewed only when the surrounding feathers are lifted. One kahu kiwi has concealed chicken and pheasant feathers as well a loop of green wool. Brown kiwi feathers were also woven to form a word on one feather cloak.

Order Galliformes, family Phasianidae – introduced game birds

Feathers from a domestic chicken (*Gallus gallus* var. *domesticus*) and a common pheasant (*Phasianus colchicus*) were examined microscopically (Table 2) for the identification of cloak feathers.

Chandler (1916: 340) observed that down from Galliformes is dense and that barbules are long, potentially reaching 5 mm. The barbules have characteristic ring-like multi-nodal structures, found on closely situated distal barbules near the base of the barb, sometimes totalling two to three nodes linked together on the barbules (Day 1966: 213). Microscopic examination of *Gallus* feathers showed the distinctive ring-like nodes in the middle of the barbules at the base of the barb. The barbules are long (Fig. 5c). Ring-like nodes are sometimes multiple and appear to move freely along the barbule, having detached from the base of small nodes in the middle of the barbules (Fig. 5d). At the middle and tip of the barb, smaller nodes appear along the barbules.

The pheasant barbules in this study were generally longer and thinner than those from *Gallus*. Node shapes varied from expanded to small nodes with detaching sections, seen as multiple 'rings' on barbules. Pheasant barbules have considerably fewer multiple rings than those from chickens, averaging one to two barbules with rings per barb. Multiple ring-like nodes appeared on distal barbules only. Barbules on turkey feathers were described by Day (1966: 213) as having neither characteristic shapes nor multi-nodal structures.

Chicken feathers of various types, breeds and colours were recorded in 25 Māori cloaks. Many feather colour combinations were present, from single to multiple feather colour combinations in various patterns. Feather colours ranged from white, cream and gold to crimson, scarlet, brown, grey and iridescent black, as well as dyed feathers. The bicoloured hackle feathers from the neck and back, as well as the breast and belly feathers of the chicken, are widespread in the cloak collection. Chicken feathers are arranged in strips, bunches and on borders in cloaks.

Strikingly coloured and patterned feathers from male pheasants were identified in the cloak collection. Breast and back feathers, as well as those from the belly, flank, nape and rump, were recorded in 15 cloaks from museum skin comparisons (Fig. 2b). Pheasant feathers are displayed in the cloaks in small bunches, as strips, or as single feathers mixed with those from other species.

Identifications of feathers from peafowl, turkey (*Meleagris gallopavo*), California quail (*Callipepla californica*) and guinea fowl present in Te Papa's cloaks were made from comparisons against birdskin images, and without microscopic analysis. Peacock (male peafowl) feathers were observed in 13 cloaks. Iridescent blue feathers from the neck, green 'peashell' feathers from the back, and black and white mottled feathers from the scapular were recorded. The iridescent 'eyes' and herl (barbs) from the tail were also visually identified in one kahu huruhuru, in which they created a unique and stunning effect (Fig. 10). Striking iridescent turkey feathers were identified in five cloaks. The most common turkey feathers in the cloaks were white-tipped, barred brown and black feathers from the upper tail, and iridescent black feathers from the breast. Different turkey feathers were incorporated into cloak patterns, in bunches or strips, or as single feathers mixed with those of other species.

Vertically striped brown and white side belly feathers of California quail, together with mottled brown, cream

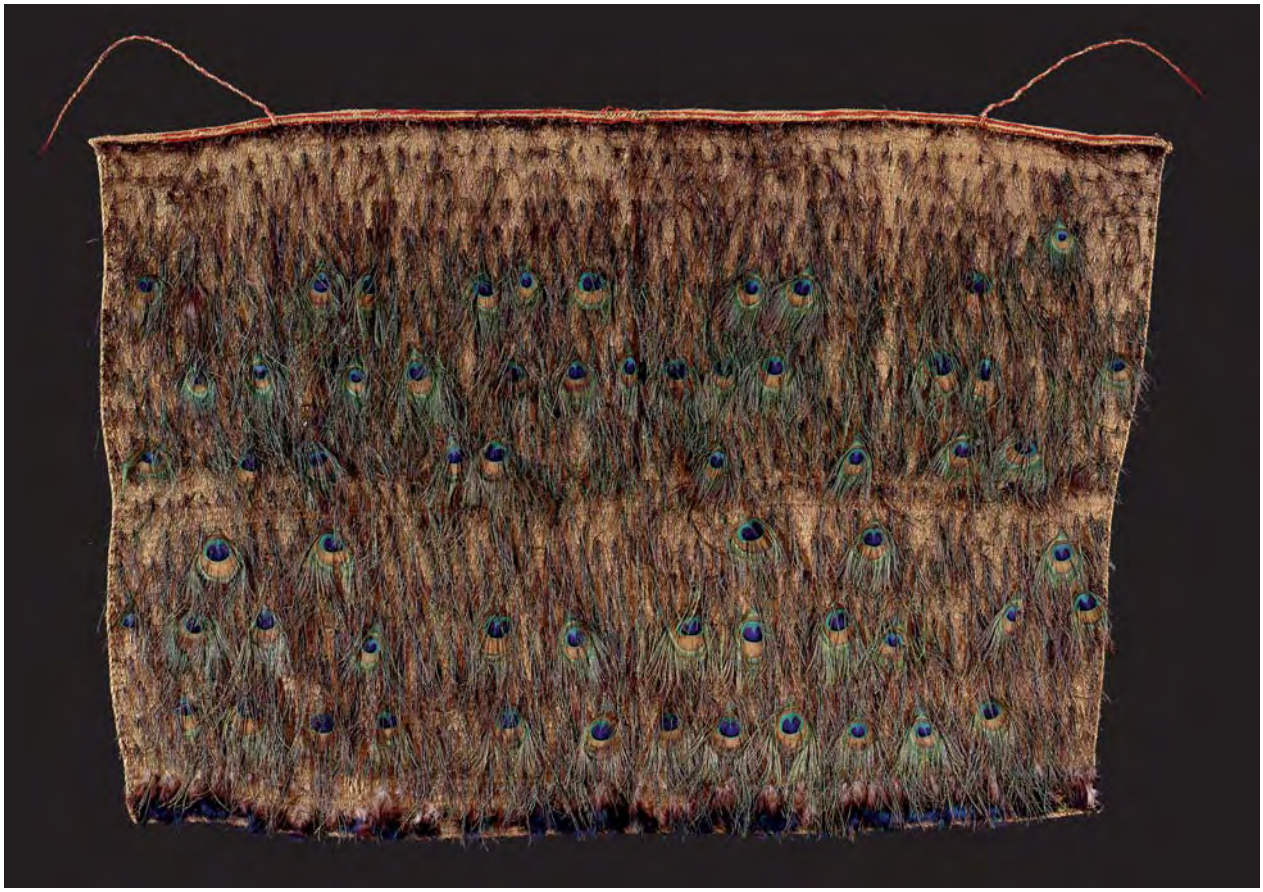

Fig. 10 Kahu huruhuru (feather cloak) with peacock-tail feathers (Te Papa ME003723).

and white belly feathers, are displayed in small bunches as contrasting colours against surrounding feathers of other species. The distinctive white-spotted grey feathers of the guinea fowl are easily identifiable in two of Te Papa's cloaks, attached as small and large bunches within cloak patterns.

Order Anseriformes, family Anatidae – ducks, geese and swans

While this order includes numerous native and introduced bird species (Gill *et al.* 2010: 30), to date only feathers of the introduced mallard (*Anas platyrhynchos platyrhynchos*) have been identified in Te Papa's cloaks. Mallards were initially introduced from the United Kingdom in 1865 (Long 1981: 55), and have since widely hybridised with native grey duck, or pārera (*A. superciliosa)*. A feather specimen from the belly of a mallard was studied microscopically to identify cloak feathers to this order. Key characteristics are summarised in Table 2.

Duck barbules are described by Chandler (1916: 329) as generally less than 1 mm long and distinctive only at the tip, where he noted between two and eight large, well-developed nodes followed by a slender tip. According to Day (1966: 214), anatids have easily recognisable, large triangular-shaped nodes, located only at the tips of the barbules and barbules can measure 1.5–2 mm long. *Anas* barbules situated at the base of the barb are simple, short, thin and thread-like, with two to four characteristic large nodes at the tips (Fig. 5e). The nodes at the tips are significantly expanded and triangular, and are followed by two to four large pronged nodes (0.01 mm long) (Fig. 5f). The distal tip of a barbule is usually a single thin point.

Mallard feathers were identified in four cloaks, originating from the underwing (white feathers), the sides (brown and black feathers) and the belly (black and white speckled or vermiculated feathers) of the bird. A single mallard feather was found concealed alongside a single white (albino) brown kiwi feather in a kahu kiwi. Mallard feathers were also found in strips on borders and in geometric patterns.

Order Procellariiformes, family Diomedeidae – albatrosses

The family Diomedeidae is represented in New Zealand by 17 species of albatross (Gill *et al.* 2010: 64). A feather specimen from the underwing of a Gibson's albatross (*Diomedea antipodensis gibsoni*) was studied and its characteristics are recorded in Table 2.

Chandler (1916: 305) described barbules from the wandering albatross (*Diomedea exulans*) as short, reaching only 1 mm long, and having forward-curved, asymmetrical prongs, either single or double, sometimes measuring up to 0.04 mm long. Microscopic examination of a feather from a Gibson's albatross confirmed that the barbules are short and wide at the base, and longer and spindly towards the tip of the barb. There are prongs all along most barbules (Fig. 6a), these being longer at the base of the barbule. Most barbules have two to four prongs at intervals, with one pair sometimes longer than the other (asymmetrical) (Fig. 6b).

White albatross body feathers, particularly from the breast and belly, were observed in Te Papa's cloaks arranged in small bunches within patterns, in strips, in borders, and as single feathers alongside those of other species.

Order Ciconiiformes, family Ardeidae – herons and bitterns

Large, mottled cream and dark brown feathers from the rump, flank, breast and upperwing of the Australasian bittern (*Botaurus poiciloptilus*) were identified in one cloak by comparisons with museum skins, without the use of microscope examination. These distinctive body feathers are large and, judging from their placement in the cloak as vertical strips, it is estimated that only one bird would have been used for the cloak (Fig. 11).

Order Accipitriformes, family Accipitridae – eagles and hawks

In New Zealand, the family Accipitridae includes only one breeding species, and few occasional visitors and extinct species (Gill *et al.* 2010: 169). A microscopic study of a feather specimen from a swamp harrier (*Circus approximans*) was made, and its diagnostic features are summarised in Table 2.

Barbule nodes are inconspicuous in the down of hawks, and often have long, asymmetrical prongs and little pigmentation, while barbules are short, 1.5–2 mm long (Day 1966: 215). Chandler (1916: 336) observed a more definite distinction, noting that in hawks the barbules are long and slender with small nodes and short prongs at the tips, whereas in falcons they have larger, heavily pigmented nodes, with slight kinks in the barbules. Dove & Koch (2010: 39) suggest that the diagnostic features of hawk feathers are long to very long barbules, with little pigment in the barbules and no pigment in the nodes. The nodes also have some spines (prongs) that appear asymmetrical in length. Barbules of the swamp harrier are long, with light to medium stippled pigment (Fig. 6c), and have lightly pigmented pronged nodes that appear asymmetrical and are closely spaced at intervals on the barbule base and tips (Fig. 6d).

Fig. 11 Close-up of swamp harrier and Australasian bittern feathers in a kahu huruhuru (feather cloak) (Te Papa ME014385).

Multiple bicoloured swamp harrier feathers (white and brown or brown and light brown) were identified in one of Te Papa's cloaks. White, brown and light brown feathers from the belly, vent and flanks were also identified using comparisons with museum skins. Swamp harrier feathers are woven in small bunches in vertical strips on a kahu huruhuru, alongside Australasian bittern, kākā and New Zealand pigeon feathers, as well as undyed wool in horizontal strips (Fig. 11).

Order Gruiformes, family Rallidae – rails, gallinules and coots

Feathers of species of weka and pūkeko (*Porphyrio melanotus melanotus*) were identified in the Te Papa cloaks. Table 2 summarises microscopic characteristics observed in a feather of a western weka (*Gallirallus australis australis*), and in one from a pūkeko.

Chandler (1916: 353) measured rallid barbules at 1.5–3.5 mm long, and described them as having short internodal spaces that are heavily pigmented along most of the barbule. Day (1966: 214) described typical rallid barbules as short and stout, 1.5–2 mm long, with two to four swollen, heart-shaped nodes at their base, which become less swollen and closer together towards the barbule tip. Weka barbules are of medium length, very wide all along but abruptly decreasing in width immediately after the prongs, producing a scaling effect (Fig. 6e). The nodal structure and internodal spaces are difficult to determine in western weka barbules, which are wide, indistinct, and heavily pigmented along most of their length, with four small prongs at intervals separating the pigmentation (Fig. 6f). Small symmetrical prongs appear all along the barbules with little or medium pigment.

Pūkeko barbules share more of the typical characteristics of other Gruiformes, and differ considerably from those of weka in microscopic features. Pūkeko barbules have four large quadrilobed nodes, at the base of distal barbules from the base of the barbs; in proximal barbules these nodes appear smaller, indicating a characteristic of asymmetry as seen in this order. These barbules appear thin, with medium to heavy pigmentation except in and just after the nodes, and are also shorter than those seen in weka. Pūkeko barbules at mid-barb have small pronged nodes all along their length and at the tip of the barb; short barbules have long prongs at the base and tips.

Weka feathers from the back, breast, belly and rump were found in 12 of Te Papa's Māori cloaks. The species could not be determined based on microscopic and skin comparisons alone. As with brown kiwi feathers, weka feathers are often turned over on cloaks, with the ventral surface facing outwards. Single or small bunches of weka feathers are dispersed among brown kiwi feathers in two kahu kiwi, and several different body feathers are identified in the main central pattern of a kahu weka (weka-feather cloak).

Pūkeko feathers in Te Papa's cloaks are mainly purple-blue feathers from the breast and belly, but white feathers from the vent under the tail and black feathers from the back are also present. Feather colours from this species range from pastel blue to royal blue, and are used in strips, small bunches and borders.

The distinctive small black and white barred belly feathers from the banded rail (*Gallirallus philippensis*) were confirmed using birdskin comparisons. These feathers adorned two cloaks in the form of strips and small bunches.

Order Columbiformes, family Columbidae – pigeons and doves

The native New Zealand pigeon (*Hemiphaga novaeseelandiae*) is most likely the only species of this order present in Te Papa's cloaks. Microscopic features of feathers from this pigeon are summarised in Table 2.

Body feathers from columbids have a significant amount of down in the breast and, particularly, in the belly. The rachis is also distinctively flattened at the calamus. Barbules from columbids have been described as having three to eight large, expanded and conspicuous nodes at the base, with another three to eight less conspicuous nodes decreasing in size towards the barbule tip, where there may be minute prongs (Chandler 1916: 361). The majority of barbules are long and measure up to 3–4 mm in length despite some variation among genera (Chandler 1916: 361; Day 1966: 214). Dove & Koch (2010) also noted some asymmetry in node sizes in distal and proximal barbules.

New Zealand pigeon feathers have typical columbid barbules, being long with four to six large crocus-shaped (four-lobed) nodes at the base of most barbules (Figs 7a,b). Node size abruptly decreases near the middle of the barbule, until there are minute or no nodes, and there may be three to four pairs of long, transparent prongs at the barbule tip. Internodal spaces are uniformly long, and barbules and nodes have little pigment.

Feathers from the New Zealand pigeon are widespread throughout the cloak collection, having been identified in 45 cloaks. The green neck feathers, and white breast and belly feathers are the most common types found. Maroon and 'teal green' back and upperwing coverts are also present to a lesser degree. The white and green feathers are used either in strips, borders or contrasting patterns. One kahu huruhuru features the green neck feathers, which covers most of the cloak.

Order Psittaciformes – parrots and parakeets

The endemic kākāpō and kākā belong to the family Strigopidae, while native parakeets belong to the family Psittacidae (Gill *et al.* 2010: 249). Feathers of all three kinds of birds from this order were identified in cloaks. Feathers from a North Island kākā (*Nestor meridionalis septentrionalis*) and a red-crowned parakeet (*Cyanoramphus novaezelandiae novaezelandiae*) were analysed microscopically and their key characteristics summarised in Table 2.

Fig. 12 Kahu huruhuru (feather cloak) with native New Zealand pigeon, kākā, tūī and parakeet feathers (Te Papa ME004275).

Chandler (1916: 365) gives key features for these birds as small heart-shaped or globular pigmented nodes along the length of the barbules, and short, lightly pigmented internodal spaces. Also, nodes are large at the base of the barbule and minute at the tip. Dove & Koch (2010: 50) suggest that the diagnostic features for Psittaciformes are the long to very long barbules, widely flared pigmented nodes along barbules, and absence of villi at the base of barbules.

Kākā barbules are long, straight and pointed towards the barb tip, and vary in width. Nodes are present along the whole length of barbules, gradually decreasing in size. Nodes from barbules at the barb base are short and expanded at the tip. At mid-barb, triangular nodes decrease to form globular nodes in the middle of the barbules, continuing to the tip. At the tip of the barb there are minute prong-like nodes, which become longer towards the tip of the barbules. There is medium to heavy pigmentation in kākā nodes, with little to medium pigment in internodal spaces.

Red-crowned parakeet barbules are also long, decreasing in length towards the barb tip. Barbules generally remain the same width along their length (Fig.7c). In the feather examined, from the middle of the downy area, barbules from the base of the barbs had more symmetrical droplet-shaped nodes in their middle. At the base of the barb and at the base of the barbules, the nodes are widely spaced, expanded and heavily pigmented except in the tips of the lobes (Fig.7d). Nodes are present all along barbules, with little to medium pigmentation in internodal spaces. At mid-barb, nodes are droplet-shaped, heavily pigmented and some have small transparent prongs. At the tip of the barb, barbules have long, thin prongs that are closely spaced.

Colour variations of kākā feathers in Te Papa's cloaks indicate that both the North Island kākā and South Island kākā (*Nestor meridionalis meridionalis*) subspecies are present in the collection, based on comparisons with museum bird skins. Kākā feathers were identified in 43 of the cloaks. Weavers primarily used the light orange to crimson-red underwing coverts (Fig. 2c) and the red-tipped belly feathers. Four of Te Papa's cloaks contain kākā feathers as their main feature. Two cloaks are catalogued as kahu kura or kākahu kura and primarily utilise the orange kākā feathers; where 'kura' may refer to the colour red or reflect high (chiefly) status. The other two cloaks, catalogued as kahu kākā or kākahu kaka, predominately feature the red or rusty-brown feathers, and may specifically be named after the bird.

Kākā feathers were recorded in cloak borders and geometric patterns, while single or small bunches have been used to lift the colour of some cloaks, a technique described by Te Kanawa (1992: 26). In this, brightly coloured feathers are used as a contrast against darker feathers in the background. Also, where single or small bunches of kākā feathers were hidden underneath the feathers of other species, it is possible they were used as possible weaver 'signatures', a concept that is discussed below.

Light green native parakeet feathers appear in strips, bunches, borders and geometric patterns. Single feathers are also used to lift the colour from surrounding feathers. Light green feathers from the breast, belly, crown (head) and back were observed. One cloak includes blue-green upperwing covert feathers, and other cloaks feature the light green head feathers tipped with red from the crown of the bird (i.e. red-crowned parakeet). Parakeet feathers were often woven into cloak patterns alongside white and green New Zealand pigeon feathers, orange kākā feathers and black tūī feathers (Fig. 12).

Kākāpō feathers from the belly, breast, back and upperwing were easily identified by comparisons with museum skin images (Fig. 2d). Only one cloak in Te Papa's collection, a kahu kiwi, featured kākāpō feathers. In this garment, green, light green and brown mottled feathers were present in the borders, along with feathers of other species; kākāpō feathers were also interspersed throughout brown kiwi feathers in the middle of the cloak, possibily again as a colour lift.

Order Cuculiformes, family Cuculidae – cuckoos

The long-tailed cuckoo (*Eudynamys taitensis*) and the shining bronze-cuckoo (pīpīwharauroa, *Chrysococcyx lucidus*) are migrants, breeding in New Zealand each spring (Gill *et al.* 2010: 261). Feathers of both species have been identified in Te Papa's cloaks. Microscopic examination was conducted on a long-tailed cuckoo feather, and data summarised in Table 2.

Chandler (1916: 365) described feathers from Cuculiformes as having long, slender barbules, at least 2 mm in length, with globular nodes in the form of rounded droplets. The nodes were large near the barbule base, and smaller towards the tip. He also noted that the internodal spaces were long, slender and heavily pigmented, particularly just before the nodes. Long-tailed cuckoo barbs are short, with medium to long barbules (Fig. 7e). The nodes at the barb base are distinct in that the pigmentation is pre-nodal, being located just before the main node on the barbules, and form a bell shape (Fig. 7f) (Dove & Koch 2010: 27). These nodes are quadrilobed and gradually decrease in size towards the tip of the barbule, where they have the same width as the barbule. There is heavy pigmentation before the nodes on barbules at the base and middle of the barb. Barbules at the tip of barbs have little to medium pigmentation, with little pigment in the nodes. The nodes are distributed all along the barbule length and are uniform in size.

Long-tailed cuckoo feathers were identified in two of Te Papa's cloaks: white breast feathers with a central brown line; white side belly or flank feathers; and vent feathers with a brown 'V' shape across the feather (Fig. 2e). Shining bronze-cuckoo feathers were identified by comparisons with images of museum skin feathers, but not with microscopic analysis. Iridescent light green and white horizontal barred feathers from the breast and belly, and iridescent green back feathers were recorded in the borders of a kahu kiwi.

Order Strigiformes, family Strigidae – owls

The morepork (*Ninox novaeseelandiae novaeseelandiae*) is the only extant native New Zealand species belonging to this family (Gill *et al.* 2010: 264), and it is also the only species from this order identified in Te Papa's cloaks. A feather from this species was used to record microscopic characteristics for the order, which are summarised in Table 2.

Barbules from feathers of Strigiformes generally have three large globular nodes at the base (Chandler 1916: 375). Pigmentation of the nodes is heavy, while the internodal space is slightly transparent. Barbule lengths are 3–4 mm long, and the internodal spaces are large (Day 1966: 215).

Fig. 13 Close-up of mottled morepork feathers in a kahu huruhuru (feather cloak) (Te Papa ME011987).

Morepork barbs are very soft, long and wispy. At the base of the barb, barbules are long and spindly, becoming straighter towards the barb tip. They measure 1–2 mm in length, with shorter barbules in the middle of the barb (Fig. 8a). The barbules at the barb base have five to seven large triangular nodes at their base that gradually decrease in size to very thin, widely spaced pigmented nodes at the tips. At the very tips of the barbules, the nodes often have small transparent prongs. Barbules from the middle and tip of the barb have three to four large triangular nodes at their base (Fig. 8b), becoming uniform in size and more closely spaced towards the tip. Generally, internodal spaces are greater in the middle of the barbules. Pigmentation is heavy in nodes, but light to medium in the internodal spaces.

Two single mottled brown, cream and white morepork belly feathers were identified in a small kahu huruhuru (Fig. 13), with one feather on either side of a vertical pattern of bluish-black tūī feathers and dark blue pūkeko feathers. The two morepork feathers are light against this dark background.

Order Passeriformes – passerines or perching birds

Feathers from at least three species of passerine – two native and one introduced – have been found in Te Papa cloaks: the tūī (*Prosthemadera novaeseelandiae novaeseelandiae*), the extinct hūia (*Heteralocha acutirostris*) and the introduced yellowhammer (*Emberiza citrinella*). Summaries for their microscopic feather characteristics are given in Table 2.

Down and nodes vary greatly among species of this large group of birds. Nodes are generally well pigmented, triangular and roughly the same size along the barbule (Chandler 1916: 383). Barbules have flattened transparent growths with knobbed ends or villi (Fig. 8e) at the proximal end or from the barbule base (Day 1966:213). Internodal spaces are transparent and exceptionally short. Passeriformes appears to be the only order of New Zealand birds with these distinctive characteristics. Passerine barbules are variable in length, ranging from 1.5 mm to 2.5 mm in Day (1966: 213), or from 1 mm to 5 mm in Chandler (1916: 382). The shape of the barbules and length of internodal spaces also vary among family groups.

In tūī, the barbules are of medium length. Villi with distinctive knobbed ends were identified on the base of barbules from the base of the barb. Barbules are slightly wider in the middle, and nodes are present all along the barbules. At the barbule base, nodes are large and quadrilobed, with rudimentary transparent prongs that develop in the top quarter of the barbule. Nodes at mid-barbule are uniform in size and generally heavily pigmented, but with little pigment in the internodal spaces except at the tips of barbules, where nodes are wider, darker and closer together. Internodal spaces are short.

Hūia barbules are very short, 0.4–1 mm long, and wide (Fig. 8c). Nodes are small and slightly triangular in shape, and present all along barbules, spaced closely with a slight decrease in size towards the tip (Fig. 8d). Villi are also present at the base of proximal barbules (Fig. 8e). Barbule widths gradually decrease along their length. Nodes in hūia feathers are heavily pigmented, but pigment in internodal spaces is light to medium. Internodal space is very short. There are some rudimentary transparent prongs on pigmented nodes at the base of some barbules, with transparent pronged nodes at the tips.

Yellowhammer feathers have few villi at the base of barbules. Nodes are trapezoidal at the base of barbules at the barb base, and globular at the middle of barbules, with minute prongs only at the very tip of the barbule. Barbule lengths in the yellowhammer are short, ranging from 0.8 mm to 1.4 mm. There is little to medium pigmentation in the barbules. Basal quadrilobed nodes are heavily pigmented, with rudimentary prongs that are lightly or not pigmented. Internodal spaces are medium to long at the base and mid-barbule, becoming abruptly shorter at the tip.

Iridescent black tūī feathers from the neck, back, breast and upperwing coverts were identified in 35 Te Papa cloaks.

Fig. 14 Close-up of a small bunch of hidden hūia feathers in a kahu kiwi (kiwi-feather cloak) (Te Papa ME003714).

These feathers were incorporated into borders, strips, geometric shapes and small bunches. Each of the two white throat-tuft feathers from a tūī (Fig.2f), identified from museum skins, adorned each side border of a cloak.

The black belly feathers from a hūia were identified in two kahu kiwi, hidden among kiwi feathers. In one cloak, small bunches of hūia feathers were hidden among those from a brown kiwi across the garment (Fig.14). The other kahu kiwi featured single hūia, kākā and New Zealand pigeon feathers hidden among the brown kiwi feathers. The last confirmed sighting of a live hūia was in 1907 (Heather & Robertson 1996: 419).

Feathers from a yellowhammer, an introduced Eurasian passerine (Gill *et al.* 2010: 322), were identified in a single kahu huruhuru. Their distinctive canary-yellow breast and belly feathers, with central vertical brown lines, were identified in two small bunches in the middle of a cloak, surrounded by feathers of other species.

Conclusions and future research

Previously, the bird species from which feathers were used in Te Papa's Māori cloaks had not been identified with precision using scientific methods or analysis, but made visually or somewhat anecdotally, with little scrutiny of the methodology or accuracy required. Using a complete and well-curated collection of bird skins, such as those at Te Papa, and an accurate microscopic examination of down proved to be a cost- and time-effective method of identifying cloak feathers. Microscopic analysis has already proven effective in identifying feather and hair fragments in archaeological material in Alaska (Dove & Peurach 2002), and in identifying Pacific and historical museum collection items in international studies (Dove 1998; Pearlstein 2010). There is potential for successfully replicating the methods used in this study to identify feathers in other significant ethnological collections, including other taonga Māori (treasures) in collections held in museums both in New Zealand and overseas.

DNA analysis has proven useful in identifying the species and sex of kiwi (Shepherd & Lambert 2008; Hartnup *et al.* 2009), but it is not always possible to extract DNA from degraded or contaminated samples, or from fragile Māori textiles in a museum collection. Studies of brown kiwi are particularly relevant to research on the history of Māori cloaks, owing to the prevalence of kiwi feathers throughout the cloak collection. Analysing the DNA of brown kiwi feathers in conjunction with the muka fibres from a cloak could possibly retrieve the geographic origin of the materials used, and therefore iwi (Māori tribe) provenance could possibly be inferred.

Isotopic analyses of feathers have proven to be an effective tool in tracing the geographical origins of birds (Hobson *et al.* 2007). The stable isotope composition of bird feathers determined by diet and ingested water is a unique geographical marker of the bird's origin. Provenance could therefore be determined by comparing isotope landscape maps of New Zealand against feathers of known provenance, and then with feathers from cloaks. However, both this method and DNA analysis require destruction of some of the feather material, and results can also be dependent on the degradation and viability of the samples used. There is also the issue of trade and gifting of cloaks, feathers and birds between iwi and Europeans that can mislead or confuse evidence of origin and ownership of items. It is therefore important that several feather and fibre samples are taken from the cloak, as this increases the likelihood that similar samples have originated from the same location, thereby revealing possible geographic origins. This in itself is new information about the materials used not previously known.

The most frequently identified bird species whose feathers feature in Te Papa's cloaks were once abundant, widespread, and ground-dwelling or low-flying. They were used by Māori for food, and their feathers used for kākahu, and other clothing and weaving, personal adornment or for inclusion on weapons and carvings (Best 1942; Orbell 2003). Particular feather types of certain species were

preferred by weavers, for example the green neck and white breast feathers of the New Zealand pigeon, and the orange underwing and red belly feathers of the kākā. Introduced birds also played an important role in changing Māori weaving in recent history. As native bird numbers declined and their use was restricted by law in the second half of the nineteenth century, the inclusion of feathers from introduced birds into Māori cloak designs not only became essential, but also introduced a whole new range of colours and designs.

The identification of feathers in Māori cloaks in other national and international collections warrants further research as it will undoubtedly lead to additional important findings and, possibly, associations in the location of origins. One of the most interesting discoveries resulting from feather identification of Te Papa's Māori cloaks has been the uncovering of hidden feathers incorporated into some cloaks. At least 30 of the 110 cloaks examined had hidden feathers or a subtle use of feathers, as well as the inclusion of other materials (e.g. wool). Presumably, these were inserted by the maker as an individual mark or memory of an event or person and, in some cases, could indicate the identity of the weaver. They may also provide an indication of the status of the wearer, and the time and environment in which he or she was living. Documentation about the use of all feathers (particularly the location of hidden ones) in other national and overseas cloak collections could test this hypothesis and, through the comparison and matching of these unique feather insertions or 'signatures', potentially provide provenance for some cloaks.

The use of bird feathers to create striking coloured patterns in Māori cloaks dating from the last two centuries is testimony to the enormous skill, ingenuity and creativity of their weavers. This research highlights the relevance of scientific identification and verification of materials held in museum collections. In addition to studying bird skins and the cloaks themselves, a better understanding of the Māori cloaks in Te Papa's collection could also be gained through the documentation of the techniques and materials employed by modern weaving practitioners. Kākahu embody the ever-changing knowledge and resources available to Māori weavers, and the information contained within the materials the weavers used will be a key to the rediscovery of their origins.

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