OPINION

Artefacts, biolog and bias in museum collection research

PRISCILLA M. WEHI*, HEMI WHAANGA† and STEVE A. TREWICK*

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† [illegible]

Museum collections are increasingl subjected to scienti c scrutin , including molecular, isotopic and trace-element anal ses. Recent advances have e tended anal ses from natural histor specimens to historical artefacts. We highlight three areas of concern that can in uence interpretation of data derived from museum collections: sampling issues associated ith museum collection use, methods of anal sis, and the value of cross-referencing data ith historical documents and data sets. We use a case stud that focuses on ki i (*Apteryx* spp.) feather samples from valuable 19th centur Māori cloaks in Ne Zealand to sho ho sampling and anal sis challenges need to be minimi ed b careful design. We argue that aligning historical records ith scienti c data generated from museum collections signi cantl improves data interpretation.

: experimenta design, haplotype frequency, kahukiwi, kiwi, Maori, sampling error, stable isotope, weaving

Museum collections are reservoirs of past and present biodiversity (Brooke 2000; Guralnick & Cleve 2005; Lister 2011). Modern genetic methods are increasingly applied to museum specimens, providing for example, insight into phylogenetic placement of recently extinct species (Cooper 2001; Shapiro 2002), DNA sexing that clarifies taxonomy (moa; Bunce 2003), composition of population samples (moorhen, Lee & Griffiths 2003), adaptive allele frequencies (blowfly, Newcomb 2005) and specimen provenance (penguin, Boessenkool 2010). Isotope and trace-element analysis of teeth, feathers and other tissues has similarly been applied to museum specimens to elucidate ontogenic movements and dietary shifts (e.g. sperm whales, Mendes 2007; seabirds, Norris 2007), migratory patterns (Hobson 2010), palaeoenvironmental change (Newsome 2010; Uno 2011) and responses to environmental change such as the transport of contaminants (Horton

making itself'. A primary conclusion was that the eastern North Island was the most prolific of cloak-making areas in 19th century New Zealand. Is this a valid inference from the data, and more importantly is this a meaningful interpretation of the history and traditions of cloak weaving? It is unclear at the outset whether the authors wish to infer ' weaving locations using kiwi DNA from feathers in the cloaks (which implies that feathers were collected from kiwi and woven at the same location) or to propose an alternative hypothesis of regional trading and exchange of materials or ' themselves, as described in oral history (in which case feathers cannot be used as indicators of weaving location). The assumption that the biological materials used to create an artefact also reflect the production location might be wrong. A carefully designed sampling strategy is essential to uncover historical weaving locations.

Sampling bias in museum collections

Any circumstance that causes a sample to be unrepresentative of the underlying population cannot provide a reliable basis for hypothesis testing. Typically, some form of randomized sampling is used (Southwood 1976) but there are several reasons why museum collections can fail in this respect. The composition of museum collections is dictated by collecting strategies that have often been, in the past at least, opportunistic and nonrepresentative (Pyke & Ehrlich 2010), based on the voracity of collectors with diverse personal objectives. Even current acquisition strategies are frequently not systematic if, for example, '…. acquisitions are made to maintain and improve... [the]… cultural and historical record of the world's cultures and civilizations, and generate public interest in the past and present' (British Museum Policy on Acquisitions 2011).

Many researchers recognize that museum collections suffer from the limitations of presence-only data, but do not recognize that understanding the reasons for data absence is critical. Absence of an artefact might reflect a true historical absence at a particular location, imperfect detection, failure to collect in that area (collector bias) or subsequent loss/damage of specimens. Imperfect detection occurs where objects or species are present but not detected by observers, for example where species are rare or cryptic, or sacred artefacts are not revealed or sold to collectors. More importantly, collections of natural history specimens and artefacts such as ' reflect the nonrandom interests, geographic movements and history of individual collectors and thus frequently asset-5374.1(-4659((collecp62.8(p81(-47t)-415.3(area)-408.9((coluD[(importantly,)-5movier.08.9(posng.)-(prestyp5.7(c9)

Museum specimens and artefacts are typically far removed from their geographical and cultural context. Nevertheless, publicly available historical records can usefully verify known details including provenance, and reveal other details. We searched the online New Zealand National Library Collection of English language newspapers, 'Papers Past' (http://paperspast.natlib.govt.nz/cgi-

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P.M.W. is a postdoctoral fellow using stable isotope analysis to answer ecological questions. She currently works on endemic New Zealand crickets (tree weta), but also has an active interest in conservation biology and TEK of indigenous peoples. H.W. is a linguist interested in discourse analysis, ethics and the digitization of indigenous knowledge. S.A.T. addresses questions in evolutionary ecology and genetics, using New Zealand invertebrates and birds, with his group at Massey University http://evolves.massey.ac.nz/. His research questions are generally centred on the evolution of species.

Supporting information

Additional supporting information may be found in the online version of this article.

Appendi S1. Contextualising museum collection development in New Zealand: The importance of provenance and historical information.

Table S1 accession numbers used in this research (based on accession numbers from previous molecular kiwi data (Hartnup 2011)), along with accompanying records from the museums (including provenance where known).

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