

SHORT NOTE

Radiocarbon ages for kakapo (*Strigops habroptilus*) (Strigopidae: Strigopinae) from the Pyramid Valley lake bed deposit, north-eastern South Island, New Zealand

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Skeletal remains of the kakapo (*Strigops habroptilus*) (Aves: Strigopidae: Strigopinae) are abundant in many late Quaternary fossil sites in New Zealand (Millener 1981; Worthy 1994; Worthy & Holdaway 1994; Worthy & Holdaway 2002), reflecting its wide distribution in the pre-human environment (Higgins 1999). Despite its geographic near ubiquity, and the importance – in view of its critical conservation status (Elliott *et al.* 2001) – of understanding *when* as well as *where* kakapo lived before human intervention the only radiocarbon age so far available for a fossil kakapo anywhere in New Zealand is the $4,170 \pm 65$ radiocarbon years Before Present (NZA 9070; Table 1) measured on a bird from the Hukanui 7A site in inland Hawke's Bay ($39^{\circ}16'43''\text{S}$, $176^{\circ}30'34.3''\text{E}$, c. 842 m a.s.l.) (Holdaway *et al.* 2002). The mean calibrated date of c. 2,700 BCE (c. 4,600 years Before Present) (Table 1) confirmed the species' presence there 1,200 years before the Waimihia eruption of Taupo Volcano

(Lowe *et al.* 2013), and c. 3,000 years before the better-known Taupo First Millennium eruption (Holdaway *et al.* 2018). On its own, however, the age cannot provide information on the dynamics of the species in relation to the environmental effects of these and other eruptions.

Although kakapo bones have been found in only very small numbers in later deposits in inland Hawkes Bay (Worthy & Holdaway 2000), they were certainly abundant elsewhere in the eastern North Island in the late Holocene, despite the effects of the continual eruptions of the central North Island volcanoes. The rarity of kakapo fossils in and around Hukanui 7A may result from the rarity of pitfall traps in the area (Worthy & Holdaway 2000), or from the prey preferences of the extinct giant harriers (*Circus teauteensis*) that accumulated the deposits. Elsewhere in the eastern and south-eastern North Island, kakapo remains are frequent in vertical cave systems (Yaldwyn 1956; Worthy & Holdaway 2000). They were also abundant in the late Holocene lowland lake bed deposit at Lake Poukawa in southern Hawkes Bay (Horn 1983).

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Table 1. Radiocarbon ages of kakapo (*Strigops habroptilus*) at Pyramid Valley, North Canterbury (this paper), and in Hukanui #7a, inland Hawkes Bay, New Zealand (Holdaway *et al.* 2002). Museum, Canterbury Museum, Christchurch, New Zealand accession number. Unreg., bone submitted for radiocarbon dating before collection registered. Mass, mass (mg) of sample submitted; UBA, 14Chrono Laboratory, Queen's University, Belfast; NZA, Rafter Radiocarbon Laboratory, GNS Science, Lower Hutt. C mass, mass (mg) of graphite; CRA, Conventional radiocarbon age (^{14}C years). SD, standard deviation of the radiocarbon measurement. $\delta^{13}\text{C}$, carbon stable isotope ratio used to normalise the radiocarbon measurement. NA, not available.

Site	Square	Museum	Mass	Lab. no.	C mass	CRA	SD	$\delta^{13}\text{C}$	Calibrated dates – BCE/CE		
									Mean	SD	Median*
Pyramid Valley	53	Av5995	162	UBA42956	1.2	2716	24	-18.1	838 BCE	29	829 BCE
Pyramid Valley	108	Av15057	155	UBA42957	1.2	1962	52	-20.6	84 CE	68	83 CE
Pyramid Valley	120	Av20136	95	UBA42958	1.2	1320	22	-19.8	730 CE	37	724 CE
Pyramid Valley	107	Av15058	221	UBA42959	1.2	3516	35	-19.8	1,798 BCE	60	1,800 BCE
Hukanui 7A	13	Unreg.	NA	NZA9070	NA	4170	65	-20.7	2,714 BCE	104	2,718 BCE

*Median calibrated date, included as it is the date at which there is an equal probability of the actual date of the bird's death being older and or younger and is therefore a valid "point date" for the presence of the species at a site.

Kakapo are particularly abundant in pitfall cave deposits of the South Island's West Coast (Worthy & Holdaway 1993), but their remains have also been recovered from both natural and archaeological sites east of the Main Divide (Worthy & Holdaway 1996; Worthy 1997, 1998, 1999; Holdaway & Worthy 1997; Wood *et al.* 2017). One eastern South Island site with kakapo is the Pyramid Valley lake bed deposit (Fig. 1; $42^{\circ}58'23.3''\text{S}$, $172^{\circ}35'49.9''\text{E}$, c. 300 m a.s.l.), which contains one of the richest late Holocene avifaunas in New Zealand (Holdaway 1990; Worthy & Holdaway 1996; Holdaway & Worthy 1997). The temporally consistent series of >140 radiocarbon ages on four species of moa (*Dinornis robustus*, *Emeus crassus*, *Euryapteryx curtus*, *Pachyornis elephantopus*) from the site (Holdaway *et al.* 2014; Allentoft *et al.* 2014) shows that birds were being preserved in the lake bed continuously for most of its 5,000-year (4,000 BCE to 1,000 CE) sedimentary history (Gregg 1972; Johnston 2014).

Early excavation methods at the site favoured recovery of moa (Aves: Dinornithiformes) and other large birds (Eyles 1955). Between 1937 and 1965, fragmentary remains of five kakapo were collected from Pyramid Valley: the 22 bones represent a minimum of four adults plus one well-grown juvenile (Holdaway & Worthy 1997). The juvenile confirmed the presence of a local breeding population. Male fledglings at least are known to remain within their natal home ranges for up to the first nine months (Higgins 1999) so it is likely that the juvenile was hatched within a few hundred metres of the lake. The species flies poorly (Oliver 1955) and adults, although they have been known to walk at least 5 km in a night, also usually remain within their home ranges of 15–50 ha (Higgins 1999).

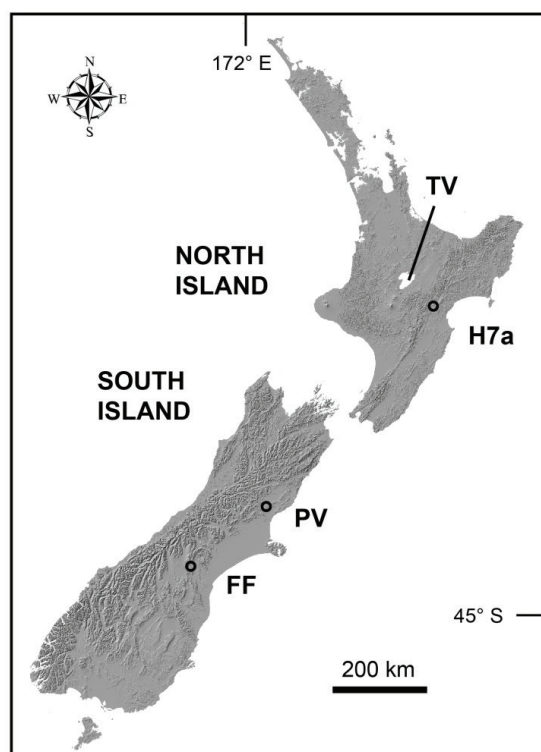


Figure 1. Location of sites with radiocarbon dated kakapo (*Strigops habroptilus*) and Taupo Volcano (TV). H7a, Hukanui 7a; PV, Pyramid Valley; FF, Finsch's Folly cave. Digital Elevation Model courtesy of the School of Earth and Environment, University of Canterbury, Christchurch.

As part of a project to develop chronologies for the “minimegafauna” at Pyramid Valley, species which have hitherto been neglected in favour of the four species of moa found there (see above), accelerator mass spectrometric radiocarbon ages were measured on the four adults at the 14Chrono laboratory, Queen’s University, Belfast, UK. Small (95–221 mg) samples of the one element (the pelvis) which could be certain to have been from different individuals, chosen to avoid features of potential morphological interest, were submitted for dating. The juvenile was represented by part of the sternum, which could not be sampled. Collagen was extracted using a method based on that of Brown *et al.* (1988), with a Vivaspin® filter cleaning method introduced by Bronk Ramsey *et al.* (2004). The conventional radiocarbon ages were calibrated to calendar years using the SHCal20 curve (Hogg *et al.* 2020) in OxCal 4.3 (Bronk Ramsey 2009) (Table 1).

The four calibrated dates ranged from c. 2,700 BCE to 730 CE (Table 1) confirming the presence of kakapo at Pyramid Valley in the late Holocene when the local vegetation was a species-rich dry forest (Burrows 1989; Holdaway & Worthy 1997). The Pyramid Valley collections are dominated by birds of kakapo size and above, so the few kakapo bones among them suggest that the local population was small. As noted above, kakapo were abundant in the Lake Poukawa lake bed deposit (Horn 1983), so the mode of deposition is unlikely to have been responsible for so few kakapo having been preserved in Pyramid Valley. The deposit lies within a c. 50 ha closed valley, which may have held only 1–4 of the 15–50 ha overlapping home ranges occupied by kakapo in the late 20th century (Higgins 1999) unless the productivity of their food species was higher in the dry forests than in their recent habitats.

It may be significant, too, that Pyramid Valley is fundamentally a predator deposit whose contents are mostly the food remains of birds of prey. Many bones of moa and New Zealand pigeons (*Hemiphaga novaeseelandiae*) in the collections have been damaged by avian predators (*pers. obs.*): Haast’s eagle (*Hieraetus moorei*) killed moa there and Eyles’s harrier (*Circus eylesi*) dismembered pigeons on overhanging branches and pieces fell into the lake (Holdaway 2015). Kakapo are likely to have been less abundant than pigeons, they have “highly cryptic” plumage (Williams 1956), and – at least today – are mostly nocturnal and crepuscular so they were unlikely to be the regular prey of either raptor (Williams 1956). As well as being cryptic on the forest floor (Williams 1956), kakapo would have been well camouflaged when feeding in the canopy (Higgins 1999). The laughing owl (*Sceloglaux albifacies*), New Zealand’s largest nocturnal predator, fed on birds smaller than kakapo (Holdaway & Worthy 1996).

Kakapo lived in the dry forests further south in the eastern South Island as well during the latest Holocene. Five individuals recovered from Finsch’s Folly cave, 160 km south of Pyramid Valley (Fig. 1) (Wood *et al.* 2017) are currently undated, but were found with other extinct birds whose remains have been radiocarbon dated (Wood *et al.* 2017). A South Island goose (*Cnemiornis calcitrans*), a Finsch’s duck (*Chenonetta finschi*), and a South Island adzebill (*Aptornis defossor*) yielded calibrated calendar dates (mean \pm SD) of 464 ± 38 CE, 724 ± 34 CE, and 465 ± 38 CE, respectively (Wood *et al.* 2017). These, along with the youngest Pyramid Valley kakapo date, all fall within the First Millennium CE.

Until Polynesian fires removed the eastern forests (McWethy *et al.* 2010), kakapo were not confined to the wet forests – podocarp or beech – or the subalpine vegetation inhabited by the relict populations before their extinction on the main islands in 20th century (Higgins 1999). Instead, kakapo populations contracted, as most species’ do (Channell & Lomolino 2000), to the peripheral, poorest habitats and their remnants did not occupy optimal habitats near the centre of the original distributions.

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