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SHORT NOTE

Mind the gap: potential implications of the chronology of the South Island adzebill (*Aptornis defossor*) (Aves: Aptornithidae) at Pyramid Valley, North Canterbury,

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The extinct South Island adzebill (*Aptornis defossor*) (Aves: Aptornithidae) is relatively abundant in the collections from the Pyramid Valley lake bed deposit (42˚58′22.54″S, 172˚35′50.12″E, Fig. 1) (Holdaway & Worthy 1997). The minimum of 11 individuals excavated so far represent 2.6% of the total non-passerine avifauna, and 5.5% of the non-passerines excluding the four species of moa (Aves: Dinornithiformes) (Holdaway & Worthy 1997). The species was third-equal with the brown teal (*Anas chlorotis*) (5.5%) among non-passerines after the New Zealand pigeon (*Hemiphaga novaeseelandiae*) (34.7%), and kaka (*Nestor meridionalis*) (6%).

Such numerical comparisons can be misleading, however, as recovery of material from the lake bed sediments was heavily biased towards large birds by the methods employed in early (pre-1970) excavations. Before 1949, individual pits were dug where probing with steel rods revealed the presence of large bones (Holdaway & Worthy 1997). From 1949, excavations were undertaken in an array of 3.66 × 3.66 m squares dug to 1.5–1.8 m, initially across the width of two squares with "spoil" shovelled back into the previous squares (Eyles 1955). Although it was claimed that "even the fragile bones of forest birds were easily detected", that the "average time for the recovery of each [moa] skeleton… was estimated at 75 minutes" (Eyles 1955: 259) suggests that much if not most of the smaller material was missed.

The number of adzebills recovered reflects their common presence as more or less intact skeletons (Holdaway & Worthy 1997) in comparison to, for example, Haast's eagle (*Hieraaetus moorei*), a bird of about the same body mass (Holdaway 1989; Holdaway 1992). Four eagles were represented by just 22 bones, whereas collections hold well over 517 adzebill bones (Holdaway & Worthy 1997). In light of the mode of excavation – which seems to have concentrated on 'mining' moa skeletons – it is perhaps remarkable that bones of at least nine tui (*Prosthemadera novaeseelandiae*), a much smaller bird than any of the above, were also recovered (Holdaway & Worthy 1997).

The Pyramid Valley fossil avifauna was deposited during the second half of the Holocene (Gregg 1972; Johnston 2014). Deposition chronologies within that time frame are available only for the four species of moa (Holdaway *et al.* 2014; Allentoft *et al.* 2014). Radiocarbon ages on others in the non-moa avifauna are only now becoming available (Holdaway 2021a,b; Johnston *et al*. In press). However, as it is apparent that the deposition conditions and local environment have varied significantly over the past 5,000 years (Johnston 2014; Johnston *et*

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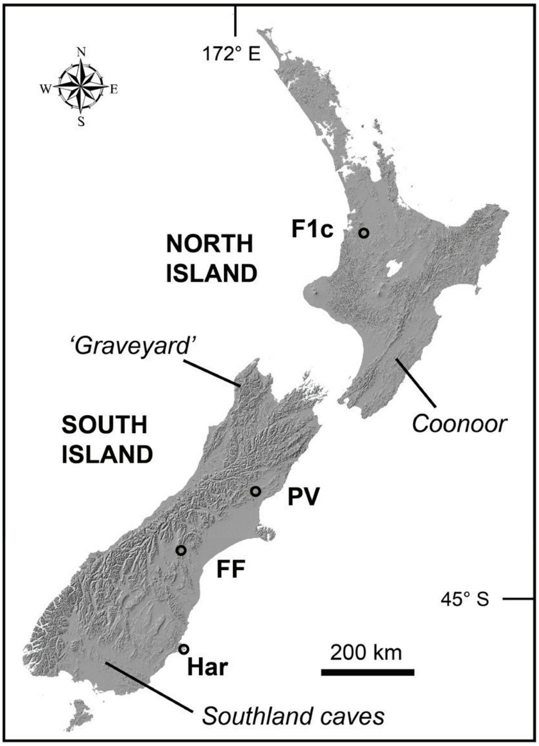

Figure 1. Location of sites for which radiocarbon ages on *Aptornis defossor* (South Island) and *A. otidiformis* (North Island) are now available. F1c, Cave F1c, Waitomo District; PV, Pyramid Valley, North Canterbury; FF, Finsch's Folly Cave, South Canterbury; Har, Harwood, Otago Peninsula. Locations in italics, sites with large samples of *Aptornis* spp. of potential use in testing the LALIA gap hypothesis. Digital Elevation Model courtesy of the School of Earth and Environment, University of Canterbury, Christchurch, New Zealand.

al. submitted), interpretations of the habitat and biology of species in the avifauna depend heavily on when the birds were present. Pyramid Valley is particularly important in this regard because the local environment is better understood from *in situ* studies than for any comparable site in New Zealand (Harris 1955; Moar 1970; Gregg 1972; Burrows 1980a, 1980b, 1989; Holdaway & Worthy 1997; Johnston 2014; Johnston *et al*. In press).

To move beyond the present concentration on moa, radiocarbon ages for individuals of five species of the "smaller megafauna" were measured to investigate relationships between their presence and contemporary conditions (Holdaway 2021a,b; Johnston *et al.* In press; this paper). Of these species, the biology of the adzebills (North and South Island) has attracted recent interest (Holdaway 1989; Holdaway & Worthy 1997; Worthy & Holdaway 2002; Wood *et al.* 2017) because they are the sole representatives of an unusual endemic family in the Gruiformes (rails, cranes, and their relatives) and appear to have been high trophic level predators (Holdaway, in Worthy & Holdaway 2002; Wood *et al.* 2017) in the pre-human ecosystem. Here I report and discuss high resolution accelerator mass spectrometry radiocarbon ages for seven of the 11 adzebills (seven of the 10 held at Canterbury Museum) from Pyramid Valley and also discuss the radiocarbon ages previously available for both the South Island and North Island (*A. otidiformis*) adzebills (Table 1).

All the ages were calibrated using the SHCal20 curve (Hogg *et al.* 2020) in OxCal4.4 (Bronk Ramsey 2009). The probability distributions of the calibrated calendar dates corresponding to the conventional radiocarbon age measurements for the Pyramid Valley birds fell into two groups, separated by a gap of several centuries in the second half of the First Millennium of the Common Era (CE) (Fig. 2A), lessened only slightly by another adzebill age (see below), from a site in South Canterbury (Fig. 2B). The more recent cluster of three was very tight, with two birds having essentially identical dates at the end of the 11th century CE (Table 1, Fig. 2). Both birds were recovered in 1948, but from different pits dug in different parts of the lake bed (Table 1) (Holdaway & Worthy 1997).

The gap in adzebill deposition began just before a period between 536 CE and 660 CE known variously as the "Dark Ages" (Helama *et al.* 2017) and the Late Antique Little Ice Age (Büntgen *et al.* 2016). This period followed two major volcanic eruptions, in 536 and 540 CE, and was characterised by a reduction in insolation and environmental disruption (Büntgen *et al.* 2016; Helama *et al.* 2017; Helama *et al.* 2018). Effects of these eruptions have not been reported before in New Zealand but the gap in deposition characterised below suggests that the adzebill population in the eastern South Island may have indeed been affected. The species could therefore be a useful environmental proxy if more ages were available.

The gap in deposition at Pyramid Valley was nearly three times longer between mean calibrated dates (762 versus 327, 239, and 298 years) than the intervals between the first four ages (Fig. 2C), the difference being significant (One-way ANOVA, F = 83.79, F_{crit} = 18.513, P = 0.012). Before the late First Millennium gap, deposition in Pyramid Valley was regular at 0.37 birds per century ($Y = 0.0037*X + 3.0638$; $R^2 = 0.9595$) (Fig. 2D). Addition of the Finsch's Folly date did not alter the pattern or the regression (Fig. 2D). After the gap, deposition was much more frequent, at 2.7 per century ($Y = 0.0268*X - 26.911$) (Fig. 2C, D). There was no break in the deposition of the four moa taxa at Pyramid Valley concurrent with that of the adzebill (Fig. 2E).

Table 1. Conventional radiocarbon ages and calibrated (SHCal20, (Hogg *et al.* 2020) calendar date ranges for South Island adzebills (*Aptornis defossor*) from Pyramid Valley (this paper), Finsch's Folly Cave and Harwood (Wood *et al.* 2017), and a North Island adzebill (*A. otidiformis*) from F1c Cave, Waitomo (Worthy & Swabey 2002). CRA, conventional radiocarbon age; SD, standard deviation of the measurement; 1σ CI, 68.3% confidence interval for calibrated date.

							Calibrated dates – BCE/CE and BP		
Site	**Square**	**Museum**	**Lab. no.**	**CRA**	**SD**	**δ^{13}C**	**Mean**	**SD**	**1σ CI**
Pyramid Valley	56,58,59	Av6019	UBA42960	2,487	24	-18.6	584 BCE	105	747–419 BCE
Pyramid Valley	VIIA	Av6025	UBA42948	2,217	26	-18.5	257 BCE	75	352–156 BCE
Pyramid Valley	62	Av6016	UBA42946	2,060	26	-19.3	18 BCE	35	56 BCE – 21 CE
Pyramid Valley	VIIB	Av6031	UBA42947	1,810	30	-19.0	280 CE	47	225–338 CE
Pyramid Valley	65	Av6018	UBA42955	1,058	34	-18.5	1042 CE	51	991–1128 CE
Pyramid Valley	48.10e	Av6032	UBA42945	977	22	-19.1	1098 CE	39	1049–1154 CE
Pyramid Valley	48.9A	Av6021	UBA42961	981	28	-19.3	1098 CE	41	1045–1152 CE
Finsch's Folly Cave	-	2013.2	Wk33991	1,645	25	-19.2	465	38	417–522 CE
Harwood, Otago	-	?	Wk23833	737	35	-19.5	1323	41	1280–1381 CE
25% marine	-	-	-	-	-	-	1389	36	1329–1429 CE
50% marine	-	-	-	-	-	-	1508	52	1443–1610 CE
F1c Cave, Layer 8	-	WO63	NZA11601	12,186	60	-19.3	14035 BP	119	14135–13875 BP

The other South Island adzebill mentioned above was from Finsch's Folly pitfall cave, near Kimbell, in South Canterbury (Fig. 1), 197 km southwest of Pyramid Valley (Wood *et al.* 2017). It died just before the start of the Late Antique Little Ice Age/Dark Ages (Fig. 2B). One of several adzebills excavated from the site, its conventional radiocarbon age (Wk33991, measured at University of California at Irvine) of 1,645 ± 25 years Before Present [= 1950 CE]) corresponds to a calibrated (SHCal20 curve) calendar date range (95.4% probability) of 390–535 CE (465 ± 38 CE, mean ± SD) (Table 1, Fig. 2B).

An age (Wk33990, also measured at UC Irvine) on a South Island goose from the same site was nearly identical (at 1,646 ± 25 years BP) (Wood *et al*. 2017). These large flightless birds (an herbivore and a predator) were sympatric there just before the eruptions, and the ensuing climate change. It would have taken some time for the vegetation and other biota to recover after a century of adverse climate, reflected in the interval after the LALIA before the next dates for adzebills from Pyramid Valley in the late 11th century CE (Table 1, Fig. 2).

The only other South Island adzebill dated was from intertidal sand flats at Harwood, on the outer coast of Otago Peninsula (Fig. 1), where the remains may have been eroded from dunes (Wood *et al.* 2017). While not mentioned by the authors, the bone may have been reworked from the Harwood archaeological site (Anderson 1983). The radiocarbon age of 737 ± 35 years BP (Wk23833, measured at UC Irvine) (Table 1) yielded calibrated (95.4%) ranges (if the bird ate only terrestrial organic matter) of 1268–1325 CE (55.1%) and 1346–1390 CE (38.4%), the dual distribution resulting from a major 'wiggle' in the carbon source curve in the 14th century. If, as Wood *et al.* (2017) suggest, the bird included some marine material in its diet, possibly littoral invertebrates, or coastal breeding sea birds, this would of course alter the calibrations so two further calibrations were made, assuming 25% and 50% marine contribution to the diet. The inclusion of 25% marine reservoir material (allowing a local marine offset ΔR of 50 ± 25 years) gave a calendar date of 1388 ± 36 CE; a 50% marine diet moved the calibrated date to 1508 ± 52 CE. Both dates would be unexceptional in the present New Zealand early Polynesian chronology.

The single radiocarbon age presently available for a North Island adzebill (*A. otidiformis*) is on a bird from F1c cave near Waitomo (Worthy & Swabey 2002) (Table 1, Fig. 1), where it lived 14,035 ± 119 calendar years BP. That places it there during the late glacial-interglacial transition, before lowland rain forest returned to the area.

The deposition pattern at Pyramid Valley presented here could be tested by dating further individuals from the site, particularly AMNH 7300, (American Museum of Natural History, New York) which is "an almost complete skeleton" collected by Robert Cushman Murphy in February 1948, and Canterbury Museum Av6033, noted as "not found" by Holdaway & Worthy (1997) and listed as comprising 91+ elements. This bird may have been sent in exchange with another museum, as was a relatively common practice until the 1970s.

Temporal patterns in adzebill distribution could

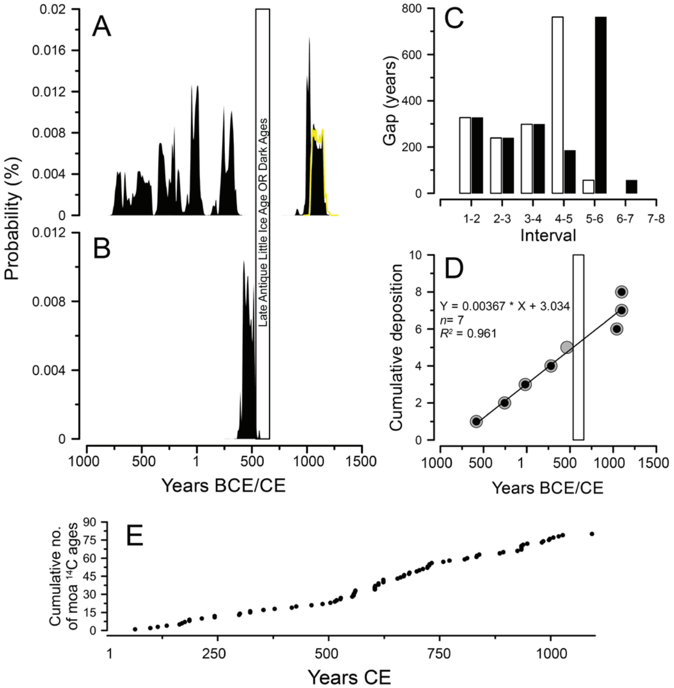

Figure 2. Radiocarbon age calibrated date probability distributions for *Aptornis defossor* in relation to period of the Late Antique Little Ice Age (LALIA). **A**, Seven dates from Pyramid Valley individuals. Note, two almost identical distributions in 11th century CE separated by yellow line. **B**, One age from an individual from Finsch's Folly Cave. **C**, years between mean calibrated dates for (open bars) seven *Aptornis* from Pyramid Valley and (filled bars) including Finsch's Folly cave individual. Interval is spacing between the deposition of individuals. **D**, Deposition (mean calibrated dates against time) of *Aptornis* in Pyramid Valley alone (solid symbols) and including Finsch's Folly cave individual (gray symbols). E, Cumulative deposition of four taxa of moa (Aves: Dinornithiformes) in the Pyramid Valley lake bed (Holdaway *et al.* 2014), showing continuity of deposition through the LALIA period for which no adzebill ages are presently available. Open box, LALIA period.

be better understood by measuring suites of ages on, for example, the 44 adzebills collected from caves in Southland (Worthy 1998). Similarly, ages for the 22 from the Graveyard deposits in the Honeycomb Hill cave system, Oparara, Northwest Nelson (Worthy 1993), would provide a useful adjunct to the small series of ages on moa from there. Again, the North Island species was "relatively common" in the collection removed from the Coonoor pit trap cave in 1914 (Worthy & Holdaway 2002) and ages and other data from those birds might throw some light on when they exercised their apparent preference for ridges, and on other aspects of their biology (Worthy & Holdaway 2002).

The ages on South Island adzebills obtained in this study comprise 70% of those available for the genus. While only hinting at patterns of distribution in spaces and time, in relation to changes in the environment, they highlight the potential value of longer series of ages on species other than moa.

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