

Faunal Extinction and Human Habitation in New Caledonia: Initial Results and Implications of New Research at the Pindai Caves

Atholl Anderson¹, Christophe Sand², Fiona Petchey³ & Trevor H. Worthy⁴

ABSTRACT

Archaeological and palaeontological investigations occurred in 2003 at the Pindai Caves in New Caledonia, where remains of prehistoric settlement exist in conjunction with the richest fossil deposits found to date on Grand Terre. Among more than 45 bird taxa in our excavations at least 20 that are locally or globally extinct are represented at levels immediately below or within the era of human occupation. These include the giant megapode, *Sylviornis* sp., the flightless swamphen, *Porphyrio kukuwiedei*, and other rails, a kagu, pigeons, a large snipe, *Coenocorypha* sp., several taxa of owls, a nightjar, and an owlet-nightjar. Unresolved problems in dating and taphonomy, however, make it difficult to specify the strength of cultural associations and thus the extent to which human activities were responsible for extinctions or extirpations. We present the first radiocarbon dates upon *Sylviornis* bone, showing that, at least, the species survived into the late Holocene. Relatively frequent occurrence of *Sylviornis* bone in the cultural levels, coupled with a radiocarbon date on a bone sample of about 3000 calBP make a case for human contact.

Keywords: New Caledonia, Pindai Caves, faunal extinction, *Sylviornis* sp., archaeology, radiocarbon dating

INTRODUCTION

Palaeontological and archaeological research in the tropical west Pacific islands during the last twenty-five years has uncovered substantial evidence of terrestrial vertebrate faunas that became extinct following the advent of prehistoric human habitation in New Ireland, although long after human colonisation (Steadman *et al.* 1999), and in Vanuatu (Mead *et al.* 2002; Bedford 2006), Fiji (Molnar *et al.* 2002; Pregill & Worthy 2003; Worthy 2000, 2001a, 2001b, 2003, Worthy *et al.* 1999), and Tonga (Pregill & Dye 1989, Steadman *et al.* 2002a, 2002b, Steadman 2006). These data now rival the better-known evidence from the eastern Pacific (Steadman 1989, 1995, 2006; Anderson 1989; Worthy & Holdaway 2002).

New Caledonia, however, has been an exception to the trend. Jean-Christophe Balouet (1990) reported 15 Quaternary fossil sites in New Caledonia, although with

minimal detail on locations (Figure 1): one each on Tiga Island, Walpole Island, Mare Island and Lifou Island; four on Isle de Pines and, presumably, seven on Grande Terre (Gilles area and Pindai, three each, and one unidentified in the north). Eleven of these localities were investigated by Balouet, 1980 to 1984, and preliminary results for material from Gilles Cave and Pindai Cave 1 were published (Balouet 1984, 1987, 1991; Balouet & Olson 1989). Material from three additional sites, investigated in 1986, remains unpublished. Significant work has been published on the crocodylian (Balouet & Buffetaut 1987) and the turtle (Gaffney *et al.* 1984) derived from these excavations.

Despite this relatively extensive research, the nature of any relationship between human settlement and most of the larger terrestrial fauna, notably of large reptiles and flightless birds, has remained obscure. In fact, even the existence of any overlap with early human settlement has rested uncertainly on few data concerning the giant megapode, *Sylviornis neocaledoniae*. An isolated radiocarbon date (Gif-6341) of about 1400–1800 calBP on a charcoal sample was reported from the Pindai Caves but with no specific provenance or association (Balouet & Olson 1989: 4). In addition, several fragments of *Sylviornis* bone were recovered from basal layers of two coastal sites of Lapita age (Balouet 1987; Sand 1996), but it was possible that subfossil material from underlying sediments had become incorporated into archaeological contexts. Our attempt to obtain a radiocarbon age on an archaeological specimen of *Sylviornis* bone from the eponymous Lapita

1 Archaeology and Natural History, CAP, Australian National University, Canberra ACT 0200, Australia.

2 Département Archéologie, Institut d'archéologie de la Nouvelle-Calédonie et du Pacifique, Noumea, New Caledonia.

3 Waikato Radiocarbon Dating Laboratory, University of Waikato, PB 3105 Hamilton, New Zealand.

4 School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW 2052, Australia

Corresponding author: atholl.anderson@anu.edu.au

Submitted 16.9.2009, accepted 2.11.2009

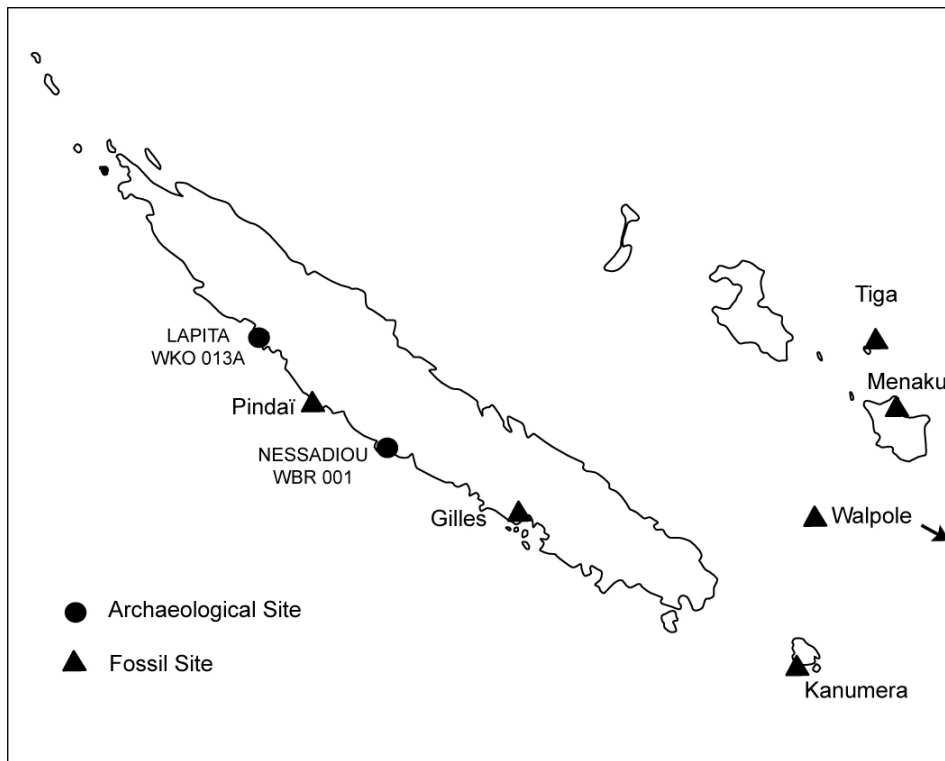


Figure 1: Location of Pindai Caves and other fossil localities in New Caledonia, and of the two Lapita sites where extinct fauna have been discovered in midden context.

site (WK 0013) failed because of a poor yield and quality of bone gelatin (sample P14475, Oxford).

In order to clarify whether extinct fauna had any human associations in New Caledonia, it was necessary to obtain more faunal material from contexts of tighter human association. New excavations were undertaken accordingly in 2003 at the Pindai Caves, the richest fossil locality recorded on mainland New Caledonia (Figure 1). As the cave deposits include both sediments without cultural remains, and some which contain cultural stratigraphy, they facilitate pursuit of two objectives. The first is to describe the late Quaternary terrestrial vertebrate fauna of New Caledonia which might have been encountered by early human colonists, and the second is to define the points at which native taxa dropped out of, or introduced taxa entered, the stratigraphic record, in relation to archaeological evidence of human habitation.

The Pindai Caves research has not yet been completed, largely because of the diversity and abundance of material from small taxa that still need to be identified and quantified. Bat, lizard, and many small bird bone assemblages remain under analysis; similarly fish bones and marine shell from archaeological deposits, and landsnails and microbotanical material from soil samples. It is probable that this work, and also research on the systematic relationships of newly-discovered taxa, will take some years yet to finish. However, stratigraphic, faunal and chronological

data are now available from our investigations in Caves A and B, and they can be used to address the questions at issue. Results from our investigations in caves C and F will be reported later.

Previous Research at the Pindai Caves

Six caves of the Pindai complex lie close together in coral limestone upraised about 5 m at the seaward tip of the Nepoui Peninsula on the northwest coast of Grande Terre (Figure 1). Cave A (Figure 2) is located at 21° 21' 005" S, 164° 57' 47.8" E; Cave B (Figure 3) at 21° 21' 005" S, 164° 57' 50.5" E; and Cave F at 21° 21' 003" S, 164° 57' 52.9" E. Cave C is joined underground to cave A (Figure 2) and entrances to Caves D and E lie about 100 m to the west of Cave C. As Caves C and F are 'walk-in', they are the easiest of human access and the least likely to entrap other vertebrates. Consequently, they have the richest cultural deposits and the fewest fossil remains. The other four are sinkholes capable of trapping non-human vertebrates, especially cursorial birds. They also contain cultural stratigraphy but it is thinner and less extensive. All of the caves broaden out into extensive underground chambers. The main site investigated by Balouet & Olson (1989: 4) was Pindai 1, in which:

The sediments in the main part of the cave consist of phosphates and magnesian clay with several intercalated layers of gypsum (2–10 cm deep) that were deposited

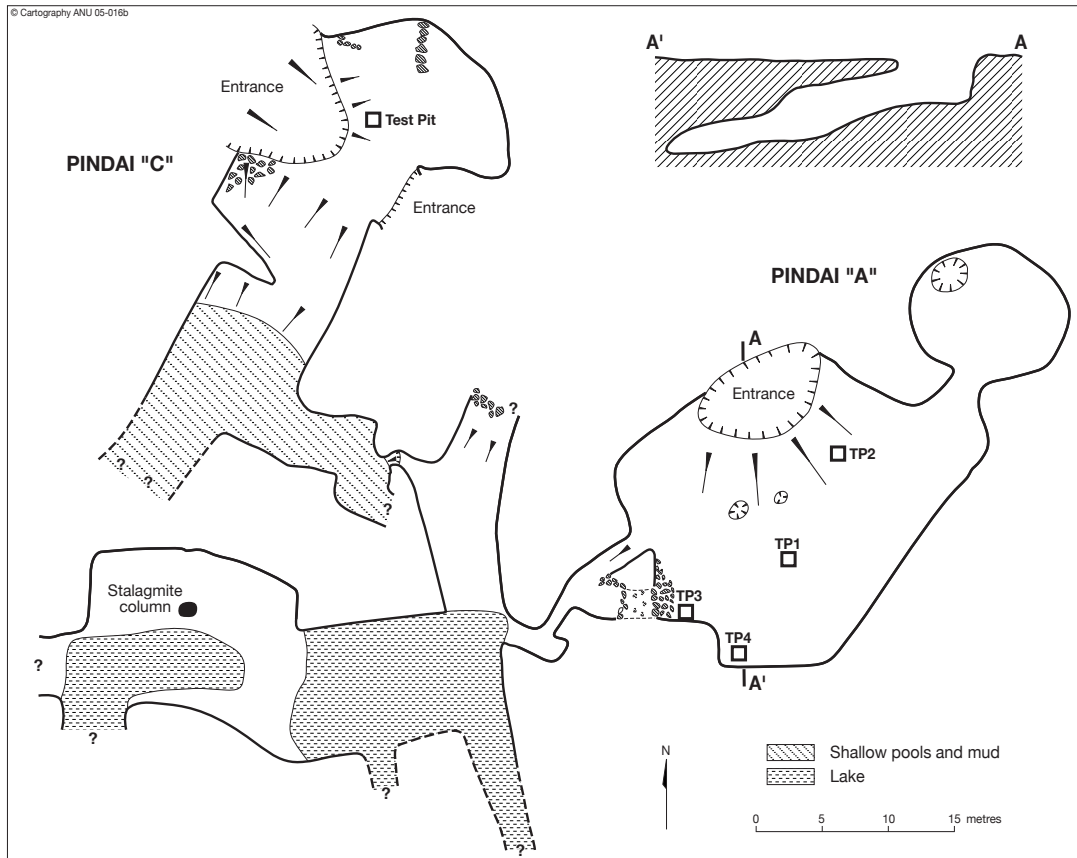


Figure 2: The Pindai Cave A and Cave C system, showing location of testpits.

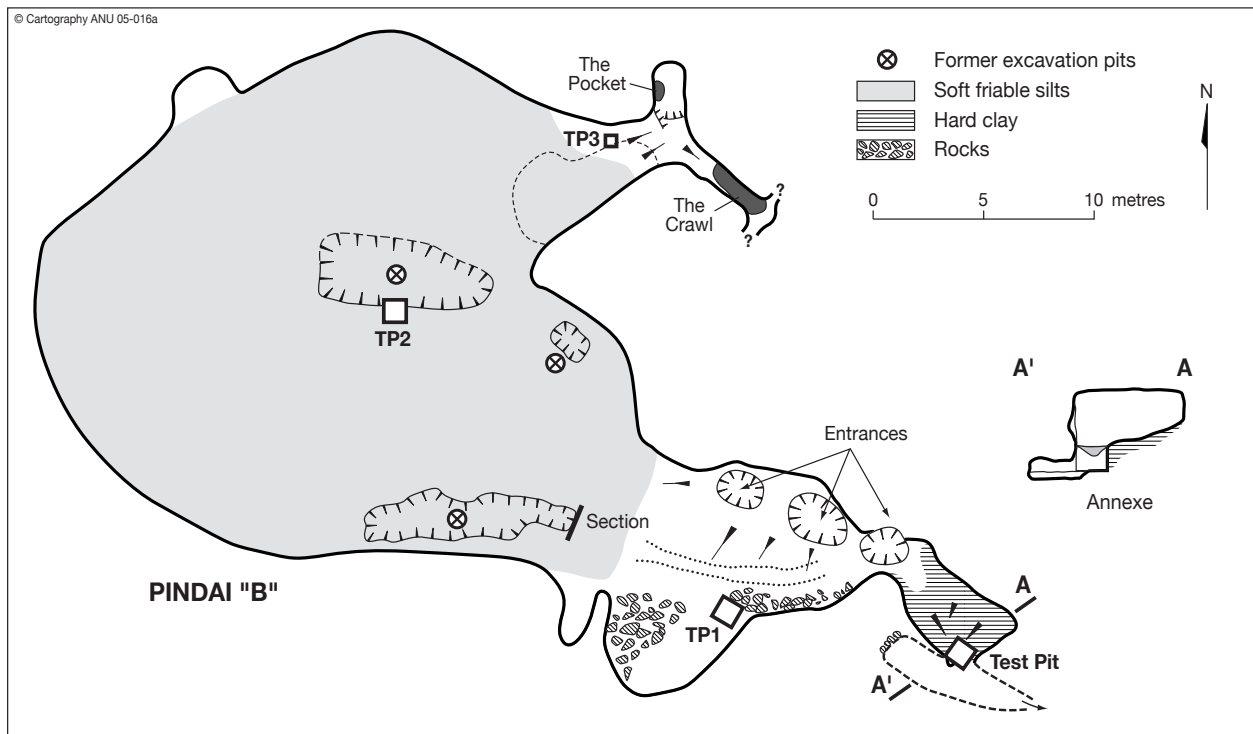


Figure 3: Pindai Cave B showing location of testpits, marginal bone-bearing patches and former excavations.

during dry periods when the cave was not flooded. Bone accumulations were found at two sites near lateral exits now filled by unstratified sediment. Bones occurred from the surface to depths of about 1.5 m, where excavation was discontinued. The concentration of bones was very high; more than 6000 bones were recovered in less than 3 cubic meters. Mollusk shells, such as *Arca*, *Ostrea*, and *Nautilus*, assumed to have been brought in by man, were fairly common through most of the deposit.

In the absence of published plans it was difficult to determine which, if any, of the sites we investigated was their Pindai 1. If shell midden was common in Pindai 1 then it might have been Cave C or Cave F, while periodic flooding suggests proximity to the underground lake, in Cave A or Cave C. Only Cave B showed clear signs of fairly recent excavations (Figure 3; but guano digging cannot be ruled out) and it had some sparse shell midden near the cave entrance. Almost no bone was found in our testpits near the cave entrance and on the open floor of the cave, or in cleaning down the baulks of the former excavations. However, high bone accumulations did occur in several small patches around the cave periphery, although it was not certain that these had been lateral exits, and they had not been excavated. Yet, on balance, and unless there is another cave not located by us, Pindai 1 was probably Cave B.

The Pindai area is known to have been occupied by humans during various periods over the last 2800 years. A survey at the tip of the peninsula in the early 1990s recovered a surface collection of a few dentate-stamped Lapita sherds. Excavations on the sheltered dune formation located about 1 km from the caves, identified occupations starting by 2750 calBP and characterised by paddle impressed Podtanean tradition pottery, before a main occupation of the seashore during the second half of the first millennium BC (Sand 1996). During this period a specific type of incurved, mostly incised pottery type, defined as the Pindai tradition, developed. Occupation of the peninsula appears to have been less regular during most of the first millennium AD, during which period incurved Balabio tradition pots, sometimes with handles, were produced. Surface collections of sherds from these are associated with visible horticultural structures and suggest long-term occupation in some areas during the second millennium AD. This was the period in which occurred intensification of the 'traditional Kanak cultural complex' associated with a specific Oundjo ceramic tradition (Sand *et al.* 2003).

FIELDWORK IN 2003

In examining the extinction-human habitation connection, our research programme at Pindai in 2003 mainly involved excavations in sinkhole Caves A and B. All testpit excavation was by natural stratigraphy and 5 cm spits, and all recovered material was screened to 2 mm. In Cave A, it was wet-sieved in an underground lake and from the other

caves in seawater. Sediment samples were taken at 5 cm intervals for sedimentary, pollen and phytolith analysis. A total of 9.5 square metres of deposit, generally ranging from 1.5 to 2 m deep was excavated. In addition, from various points around the cave walls and elsewhere, pockets of natural deposit rich in bone were excavated over a total of 5 square metres. Material from these was recorded and screened as for the testpits. In all, about 16.5 square metres of deposit were excavated; approximately 13 cubic metres. From this, about 2 tonnes of screened material were removed to the Department of Archaeology of New Caledonia, Noumea, to be cleaned and sorted into categories for further analyses.

The main excavations were in Cave A. Three excavations were completed. TP1 contained sparse shell midden in the top 40 cm but nothing below that down to 160 cm depth where a weathered limestone floor was emerging. TP2 on the talus slope was abandoned at 10 cm on impenetrable boulders. The two most productive testpits, TP3 and TP4, were located close to the cave wall in the lowest part of the floor (Figure 2). Both contained scattered cultural material, particularly lenses of ash and charcoal plus sparse ceramic sherds. The main difference between TP3 and TP4 was that in the former many limestone rocks were found in the lower cultural levels.

In TP3, cultural material (including midden shell and bone, charcoal and ceramics) was found from the surface down to about 85 cm depth where it terminated in a thin layer of manganese-stained rock and concretions, below which, in layer E (Figure 4), bone continued to be recovered within a compact silty gravel containing abundant shells of *Placostylus* sp. land snails. In TP4 a single, small sherd was recovered as deep as 111 cm, possibly having fallen down a root-tunnel, crack or landcrab hole, but otherwise cultural material extended to about 90 cm depth, in layer H (Figure 5) where, as in TP3, the sediment became compact and gravelly and *Placostylus* sp. shells began to appear. The latter were abundant in layer I where there were also streaks of manganese oxide. The *Placostylus* sp. shells show no signs of cultural breakage or burning and as they are mostly confined to a single layer (layer E in TP3, layer I in TP4) associated with manganese staining they probably represent a period of waterlogging prior to human occupation. Below the compact sediment, friable guano and silt, mostly lacking any rocks, bone or shell, extended down to limestone, interpreted as the natural cave floor, at 1.7 m depth in TP3, and to weathered limestone and grit at 2.1 m depth in TP4 (Figure 6).

In cave B, the natural stratigraphy consisted very largely of guano. In the small annexe there was abundant silt infill mixed with the guano, but in the main chamber only a slight admixture. The stained layer found in Cave A was not seen and, except near the surface, there were no signs of human habitation. Cave B has several very small entrances and is for the most part fully dark, which doubtless discouraged human habitation, whereas cave A has a

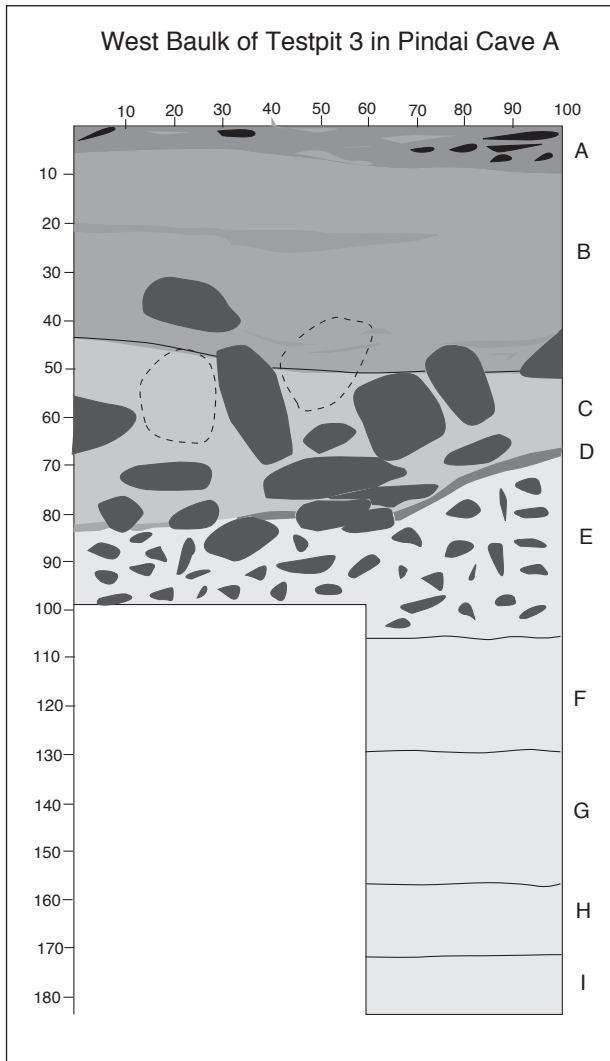


Figure 4: Stratigraphy of TP3 in Cave A. Scales in cm. Layers: A= Dark-brown, soft sediment with lenses of charcoal, ash and calcite; B= Red-brown friable silty loam with lenses of charcoal and ash. Some shell near the bottom, mostly *Placostylus* landsnails; C= Friable, red-brown silt, sand and fine gravel around limestone boulders, with few charcoal lenses; D= thin band of highly weathered rocks stained blue-black, possibly by manganese; E= compact orange-brown silt and clay with many weathered limestone pieces, and stalagmites. *Placostylus* sp., abundant and increasing with depth. F and G = dark-brown (F) and ochre-coloured (G) soft sediment and guano. No rock or faunal remains. H= yellow-orange limestone sand, gravel and pebbles. No faunal remains. I= hard limestone rock.

large entrance and is comparatively light and airy. In Cave B the open pits from former excavations were visible. Our investigations included three testpits in the main chamber (Figure 3). TP1 contained modern material amongst a shallow deposit of sparse shell midden. TP2 found only soft, friable deposits of silt and guano, and TP3 similarly, but

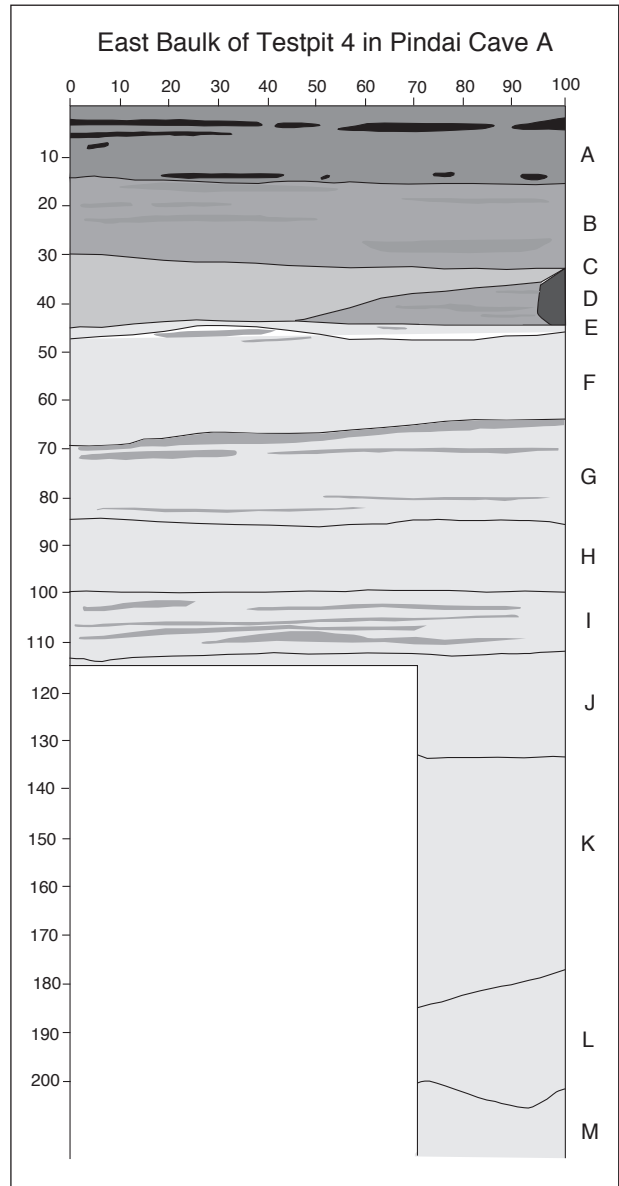


Figure 5: Stratigraphy of TP 4. Layers: A as in TP3; B= Red-brown friable silty loam with lenses of fine dark-brown silty loam, charcoal and ash; C= Friable, red-brown silt, sand and fine gravel with few charcoal lenses; D= thin layer of compact white calcite with specks of charcoal; E= Friable, red-brown silt, sand and fine gravel with few charcoal lenses; G= Soft red-brown silt and guano with dark bands and flecks of charcoal; H= Compact orange-brown clay, silt and gravel. Some *Placostylus* and fragments of large bone. I= Compact orange-brown clay, silt, gravel and stones. Abundant *Placostylus* and fragments of large bone amongst black smears (manganese?) and few pieces of charcoal. One sherd at 110 cm. J= Soft orange-red silt and guano. Sparse bone fragments. No shell or stone; K= Brown, damp silt and guano. No stone, shell or bone; L= Ochre-coloured silt, guano and fine gravel. No bone, shell or stone. Ochre-yellow grit with pieces of weathered limestone. No shell or bone.



Figure 6: Excavations in Cave A. *Above*: west baulk of testpit 3. *Below*: south baulk of testpit 4 (Images: Atholl Anderson).

shallow and lying on limestone. No bone of extinct fauna came from these. In contrast, both in the main cave (The Pocket, The Crawl) and in an annexe of Cave B, there were very rich natural deposits of bone, especially of *Sylviornis*, concentrated against the cave walls.

In Caves C and F, testpits of one square metre each were excavated. Dense deposits of ash and midden, notably of marine shell, and ceramics were found down to 90 cm depth and they were mixed amongst placed-stone features that had probably been ovens. Beneath the cultural stratigraphy, as in Cave A, were sediments with abundant *Placostylus* sp. landsnail shells and then silt with lizard, small bird and bat bone. Detailed results of the excavations in Caves C and F will appear elsewhere.

FAUNAL REMAINS

Cave A testpits 1 and 2

Faunal remains, consisting mainly of small bird, lizard, microbat and rat bones were sparse in these testpits. *Rattus exulans* was present throughout the top 40 cm and *Rattus norvegicus/rattus* and *Mus* occurred in the upper 10 cm, along with bones of the frog, *Litoria aurea*. This species is generally assumed to have been introduced historically from Australia, and our data in these testpits record it only in the uppermost deposits which were formed or re-deposited in the historical era. One chicken (*Gallus gallus*) bone in spit 2 of TP2 was the only example of this domesticated found in our investigations. A few fish bones, and a human molar in spit 3 TP1 indicate a human presence, but the state of preservation of the single *Sylviornis* bone in TP2 indicates that it was reworked from older deposits.

Cave A testpit 3

The fauna from this testpit (Figure 4) is the most rich and diverse assemblage found in our investigations. The non-bird bones have yet to be enumerated but the trends are evident. European introduced rodents occurred only in spit 1. *Rattus exulans* was abundant down to 30 cm depth, with none below 45 cm depth. Occasional *Rattus exulans* bones in samples below that depth had probably fallen into the excavation from the soft sediment of the baulks judging by their relatively unstained and unweathered appearance, compared to most bones from the deeper layers. It seems that *R. exulans* was not in the vicinity until the period of deposition of spit 10, 45–50 cm depth and above. Fish bones are regular but sparse to about 75–80 cm depth with a few occurring as deep as 155 cm. Lizards are few until 75 cm, then are abundant down to 110–115 cm and few at deeper levels. Bats are few throughout.

Turtle bone is present near the surface of the site and snake (probably sea snake) remains occur down to 70 cm depth; the turtle is probably anthropogenic in deposition.

There was a single bone of a large goanna *Varanus* sp. and two bones of the endemic crocodylian *Mekosuchus* sp.. The extinction of both in New Caledonia is assumed to be due to anthropogenic causes, yet evidence is lacking of interactions of these taxa with humans. *Mekosuchus* was represented by a mandible fragment at 60–65 cm. This is about 20 cm above that at which we infer an initial human presence, indicating first evidence of possible overlap of *Mekosuchus* with humans in New Caledonia, although re-deposition cannot be ruled out.

The faunal trends in non-bird remains indicate a major change in faunal deposition at 80–85 cm depth, the level at which we infer the arrival of people in the cave's vicinity. Before then, the abundance of lizard bone in particular suggests the use of the cave by the owl, *Tyto letocarti*, and then its absence or much reduced presence. However, in the uppermost layers deposition of rat bones is undoubtedly due to the activities of *Tyto alba*.

Sylviornis bone fragments were relatively common in this excavation. The species had a regular presence below 40 cm depth, with just one occurrence above this being at 10–15 cm. The observed preservation state of the specimens below 65 cm was consistent with that of other bones in those levels, but variations in %N (below) are indicative of varied protein retention in the bone, suggesting mixing of material from different preservation contexts.

At least 43, possibly 45, taxa of birds, excluding passerines, were recorded in TP3 (Table 1, Table 2). There is an abrupt change in faunal abundance at 110 cm depth. In part this reflects the much smaller sample below 100 cm where the excavation was restricted to an area of 0.4 × 0.4 m, but there was also a very clear decline in bird, bat and lizard bone abundance at the base of layer E. Total bird bone numbers and diversity are high between 110 and 75 cm depth, above which there are few species and low numbers of birds. As 75 cm is also the level at which lizard numbers drop dramatically, the existence of owls in the cave during deposition of the levels 110–75 cm is further indicated. That is also consistent with the majority of bones accumulated in the site being from relatively small species.

Cave A, testpit 4

The human occupation levels in TP4 are slightly deeper than in TP3, extending to 90 cm depth, but faunal remains are less abundant overall. Bird bone occurred most frequently in the lower human occupational levels (Table 3) and continued below them.

The non-passerine bird bone has been identified for TP4 (Table 3) and it largely reflects the trends evident in TP3. Testpits 3 and 4 had similar faunal ranges, differing only by the addition of a single species (*Megapodius molistructor*) represented by one bone at 110–115 cm depth in TP4. As in TP3, *Sylviornis* bone is found in several hu-

Table 1. Summary of avifauna from Testpits 3 and 4, Cave A, Pindai. Under status, 'E' = extinct globally, and 'e' = extinct locally; 'magn' = 'the size of'.

Cave A Testpit 3 and 4	Common name	Status
<i>Fregetta grallaria</i>	White-bellied storm petrel	
<i>Pterodroma magn P. brevipes</i>	Collared petrel	
<i>Pseudobulweria magn P. rostrata</i>	Tahiti petrel	
<i>Sylviornis neocaledoniae</i>	Giant megapode	E
<i>Megapodius molistructor</i>	Extinct scrubfowl	E
<i>Coturnix cf C. pectoralis</i>	Stubble quail	e
<i>cf Pandion haliaetus</i>	Osprey	
<i>Accipiter fasciatus</i>	Brown goshawk	
<i>Accipiter haplochrous</i>	White-bellied goshawk	
<i>Accipiter efficax (magn fasciatus)</i>	Extinct goshawk	E
<i>Haliastur sphenurus</i>	Whistling kite	
<i>Turnix varia novaecaledoniae</i>	New Caledonian painted button-quail	e
<i>Gallirallus philippensis swindellsii</i>	Buff-banded rail	
<i>Rail cf Lewinia pectoralis</i>	Lewin's rail	e
<i>Tricholimnas lafresnayanus</i>	New Caledonian rail	E
<i>Porphyrio kukwiedei</i>	New Caledonian swamphen	E
<i>Porphyrio melanotus</i>	Purple swamphen	
<i>Porzana tabuensis</i>	Spotless crane	
<i>Rhynochetos orarius/jubatus</i>	Kagu	E
<i>Charadrius bicinctus</i>	Double-banded plover	
<i>Coenocorypha sp</i>	Extinct New Caledonian snipe	E
<i>cf Caloenas canacorum</i>	Extinct New Caledonian pigeon	E
<i>Gallicolumba stairi</i>	Friendly ground-dove	E
<i>cf Gallicolumba longitarsus</i>	New Caledonian ground-dove	E
<i>Columbid sp. small</i>	Pigeon	
<i>Columbid sp. 1</i>	Pigeon	E
<i>cf Columba vitiensis</i>	White-throated pigeon	
<i>cf Ducula goliath</i>	New Caledonian Imperial-pigeon	
<i>cf Ducula pacifica</i>	Pacific Imperial-pigeon	
<i>?Drepanoptila holosericea</i>	Cloven-feathered Dove	
<i>Ptilinopus cf greyii</i>	Red-bellied Fruit-Dove	
<i>cf Chalcophaps indica</i>	Emerald dove	
<i>Cyanoramphus saissetti</i>	New Caledonian Parakeet	
<i>Chamosyna diadema</i>	New Caledonian Lorikeet	e
<i>Eunymphicus cornutus</i>	Horned parakeet	e
<i>Chrysococcyx lucidus layardi</i>	Shining bronze-cuckoo	
<i>Eudynamys taitensis</i>	Long-tailed cuckoo	
<i>Cacomantis flabelliformis</i>	Fan-tailed cuckoo	
<i>Tyto alba</i>	Barn owl	
<i>Tyto letocarti</i>	New Caledonian owl	E
<i>Ninox novaeseelandiae</i>	Boobok owl	e
<i>Aegotheles savesi</i>	New Caledonian owlet-nightjar	e
<i>Eurostopodus exul</i>	New Caledonian nightjar	E
<i>Collocalia esculenta</i>	Glossy swiftlet	
<i>Collocalia spodiopygia</i>	White-rumped Swiftlet	
<i>Todiramphus sanctus</i>	Sacred kingfisher	
Passerines	songbirds	

Table 2. Summary of fauna, by NISP and depth, from Testpit 3, Cave A, Pindai. Faunal status, as follows: H = historically or recently known, E = extinct, V = vagrant.

Cave A Testpit 3–NISP	St	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65	65–70
<i>Fregatta grallaria</i>	H														
<i>Pterodroma magn P. brevipes</i>	H														
<i>Pseudobulweria magn P. rostrata</i>	H														
<i>Sylviornis neocaledoniae</i>	E			1						2		1	2	4	2
<i>Coturnix cf C. pectoralis</i>	E														
<i>cf Pandion haliaetus</i>	H														
<i>Accipiter fasciatus</i>	H						3								
<i>Accipiter haplochrous</i>	H														
<i>Accipiter effcax (magn A. fasciatus)</i>	E												1		
<i>Haliastur sphenurus</i>	H														
<i>Turnix varia novaecaledoniae</i>	H	4				1	2	1		3	1				2
<i>Gallirallus philippensis swindellsii</i>	H							1							
Rail <i>cf Lewinia pectoralis</i>	E														
<i>Tricholimnas lafresnayanus</i>	H			1			1								1
<i>Porphyrio kukwiedei</i>	E														
<i>Porphyrio melanotus</i>	H		3	1	2				1		1	1	3	1	4
<i>Porzana tabuensis</i>	H														2
<i>Rhynochetos orarius/jubatus</i>	E														1
<i>Charadrius bicinctus</i>	V														
<i>Coenocorypha n. sp.</i>	E					1									
<i>cf Caloenas canacorum</i>	E														
<i>Gallucolumba stairii</i>	E														
<i>cf Gallucolumba longitarsus</i>	E														
<i>Gallucolumba sp. cf G. stairi</i>	E														
<i>Columbid sp. small</i>	?														
<i>Columbid sp. 2</i>	E												1		
<i>cf Columba vitiensis</i>	H										2				
<i>cf Ducula goliath</i>	H														
<i>cf Ducula pacifica</i>	H														
? <i>Drepanoptila holosericea</i>	H														
<i>Ptilinopus cf P. greyii</i>	H														
<i>cf Chalcophaps indica</i>	H														
<i>Cyanoramphus saisseti</i>	H														
<i>Charmosyna diadema</i>	H														
<i>Eunymphicus cornutus</i>	H												2		
<i>Chrysococcyx lucidus layardi</i>	H					1									
<i>Eudynamis taitensis</i>	V														
<i>Cacomantis flabelliformis</i>	H														
<i>Tyto alba & cf T. alba</i>	H	3	1					4	2						
<i>Tyto letocarti & cf T. letocarti</i>	E													1	
<i>Ninox novaeseelandiae</i>	E											1			
<i>Aegotheles savesi</i>	H									1			3		
<i>Eurostopodus exul</i>	E														
<i>Collocalia esculenta</i>	H									1		1		1	1
<i>Collocalia spodiopygia</i>	H	1				2	1	9	5	5	8	8	7	11	11
<i>Todiramphus sanctus</i>	H												1		1
Passerines	H	33	12	15	7	12	20	22	12	11	7	16	7	13	9
Total identified bird		41	16	18	9	17	27	37	20	23	19	28	27	31	34

continued over

Table 2. Continued.

Cave A Testpit 3–NISP	70–75	75–80	80–85	85–90	90–95	95–100	100–110	110–115	115–125	125–135	135–145	145–155	155–165
<i>Fregetta grallaria</i>						2	1						
<i>Pterodroma magn P. brevipes</i>			2	2	2		5						
<i>Pseudobulweria magn P. rostrata</i>				3	1								
<i>Sylviornis neocaledoniae</i>	6	9	4	4	9	7	12				1		
<i>Coturnix cf pectoralis</i>				1			1						
<i>cf Pandion haliaetus</i>	1												
<i>Accipiter fasciatus</i>				1									
<i>Accipiter haplochrous</i>				1									
<i>Accipiter efficax (magn A. fasciatus)</i>													
<i>Haliastur sphenurus</i>			1										
<i>Turnix varia novaecaledoniae</i>		12	18	36	107	36	247						1
<i>Gallirallus philippensis swindellsii</i>						1	2						
<i>Rail cf Lewinia pectoralis</i>					2								
<i>Tricholimnas lafresnayanus</i>		1	1	1	6	2	14						
<i>Porphyrio kukwiedei</i>		1		2		1							
<i>Porphyrio melanotus</i>	1		1										
<i>Porzana tabuensis</i>							3						
<i>Rhynochetos orarius/jubatus</i>	1	4		2		1							
<i>Charadrius bicinctus</i>							1						
<i>Coenocorypha n. sp.</i>			6	15	20	12	50			1			
<i>cf Caloenas canacorum</i>				1	1		3						
<i>Gallicolumba stairii</i>							2						
<i>cf Gallicolumba longitarsus</i>							1						
<i>Gallicolumba sp. cf stairii</i>		2		3		3	16			1			
<i>Columbid sp. small</i>							5						
<i>Columbid sp. 2</i>					3	1	9						
<i>cf Columba vitiensis</i>						5	2						
<i>cf Ducula goliath</i>					1		1						
<i>cf Ducula pacifica</i>	1						1						
<i>?Drepanoptila holosericea</i>		1			1								
<i>Ptilinopus cf P. greyii</i>				2									
<i>cf Chalcophaps indica</i>					4	1	2						
<i>Cyanoramphus saisseti</i>		2	1	3	9	1	19						
<i>Charmosyna diadema</i>									1				
<i>Eunymphicus cornutus</i>	1	1	4	17	9	7	38		1		2		
<i>Chrysococcyx lucidus layardi</i>					1								
<i>Eudynamys taitensis</i>							1						
<i>Cacomantis flabelliformis</i>					1	1							
<i>Tyto alba & cf T. alba</i>				1	1	1	4						
<i>Tyto letocarti & cf T. letocarti</i>				1		1	1						
<i>Ninox novaeseelandiae</i>				2	3	8	15						
<i>Aegotheles savesi</i>	1	3	5	11	34	17	92	1		1		1	
<i>Eurostopodus exul</i>					1		1						
<i>Collocalia esculenta</i>	3	3	3	3	2	2	4						
<i>Collocalia spodiopygia</i>	18	12	18	5	10	4	10						
<i>Todiramphus sanctus</i>				1	2		2						
Passerines	23	51	124	131	280	108	468		2	4		2	
Total identified bird	56	102	188	249	510	222	1033	1	4	7	3	3	1

Table 3. Summary of fauna, by NISP and depth, from Testpit 4, Cave A, Pindai.
Faunal status, as follows: H = historically or recently known, E = extinct, V = vagrant.

Cave A Testpit 4–NISP	St	0–5	5–10	10–15	15–20	20–25	25–30	30–35	35–40	40–45	45–50	50–55	55–60	60–65
<i>Pterodroma magn brevipes</i>	H													
<i>Sylviornis neocaledoniae</i>	E												2	
<i>Megapodius molistructor</i>	E													
<i>Coturnix cf pectoralis</i>	E													
cf <i>Pandion haliaetus</i>	H													
<i>Accipiter fasciatus</i>	H													
<i>Accipiter haplochrous</i>	H													
<i>Accipiter effcax</i> (magn <i>fasciatus</i>)	E													
<i>Haliastur sphenurus</i>	H													
<i>Turnix varia novaecaledoniae</i>	H	1			1	1	3	2	1			4	6	2
<i>Gallirallus philippensis swindellsi</i>	H						1							
<i>Tricholimnas lafresnayanus</i>	H					1								
<i>Porphyrio kukwiedei</i>	E													
<i>Porphyrio porphyrio</i>	H			1								1		
<i>Porzana tabuensis</i>	H													
<i>Rhynochetos orarius/jubatus</i>	E											1	1	
<i>Coenocorypha</i> sp.	E										1	1		
<i>Gallicolumba stairi</i>	E													
<i>Gallicolumba</i> sp cf <i>stairi</i>	E							1						
<i>Columbid</i> sp.	E					1			1				2	
cf <i>Columba vitiensis</i>	H													
cf <i>Ducula goliath</i>	H												1	
cf <i>Ducula pacifica</i>	H													
<i>Cyanoramphus saisseti</i>	H													
<i>Chamosyna diadema</i>	H													
<i>Eunymphicus cornutus</i>	H													
<i>Chrysococcyx lucidus layardi</i>	H													
<i>Eudynamys taitensis</i>	V													
<i>Cacomantis flabelliformis</i>	H													
<i>Tyto alba</i> & cf <i>T. alba</i>	H					1			1		1			
<i>Tyto letocarti</i> & cf <i>T. letocarti</i>	E													
<i>Ninox novaeseelandiae</i>	E													
<i>Aegotheles savesi</i>	H											2		
<i>Eurostopodus exul</i>	E													
<i>Collocalia esculenta</i>	H													
<i>Collocalia</i> sp.	H					1	1	2	5	11	7	3	5	2
<i>Todiramphus sanctus</i>	H													
Passerines	H	6	1	2	4		4	3	8	10	7	10	12	7
Total identified bird		7	1	3	5	5	9	8	16	21	16	22	29	11

continued over

man occupational levels of TP4 up to about 60 cm depth, but no other extinct species is represented in the human occupational levels.

New and rare bird records from Cave A

Amongst the birds are taxa new or rare for New Caledonia (Table 1). The stubble quail *Coturnix pectoralis* has not been recorded before in New Caledonia (Figure 7). Two bones in TP3 include a complete humerus and part coracoid, both distinctive elements. The species lives in north-east Australia so its presence is not unexpected in the dry

ecosystems of western New Caledonia.

A ‘white throated nightjar’ *Eurostopodus mystacalis exul* Mayr is known from a single ‘type’ female specimen collected in 1939 on Mt Panié (Higgins 1999:1012; Barré & Dutson 2002), which was considered most similar to, but differed from nominate *E. mystacalis* on plumage colour and smaller size: wing length 184 mm, tail length 138 mm, weight 77g versus *E. mystacalis* female ranges of 243–268 mm, 149–168 mm, 121–162 g (Higgins 1999:1011). The measurements of *E. exul* are closest to those of the spotted nightjar *E. argus* (females, wing 204–235 mm, tail 137–185 mm, weight 72–107 g, Higgins 1999:1022). The bones of

Table 3. Continued.

Cave A Testpit 4–NISP	65–70	70–75	75–80	80–85	85–90	90–95	95–100	100–105	105–110	110–115	115–125
<i>Pterodroma magn P. brevipes</i>						2		1	2	1	
<i>Sylviornis neocaledoniae</i>	1		1		2	1	11	4	2	6	
<i>Megapodius molistructor</i>										1	
<i>Coturnix</i> cf <i>C. pectoralis</i>										1	
cf <i>Pandion haliaetus</i>											
<i>Accipiter fasciatus</i>											
<i>Accipiter haplochrous</i>							2		1		
<i>Accipiter efficax</i> (magn <i>A. fasciatus</i>)											
<i>Haliastur sphenurus</i>											
<i>Turnix varia novaecaledoniae</i>	2		6		12	25	47	66	43	50	1
<i>Gallirallus philippensis swindellsii</i>			1	1							
<i>Tricholimnas lafresnayanus</i>	2		2	1			1			1	1
<i>Porphyrio kukwiedei</i>						1		1			
<i>Porphyrio melanotus</i>											
<i>Porzana tabuensis</i>			1		1		2				
<i>Rhynochetos orarius/jubatus</i>						1	1		1		
<i>Coenocorypha</i> sp.						6	9	9	7	11	
<i>Gallinula stairi</i>							1				
<i>Gallinula</i> sp. cf <i>G. stairi</i>											
<i>Columba</i> sp.						6		9	9	4	
cf <i>Columba vitiensis</i>							1				
cf <i>Ducula goliath</i>								1			
cf <i>Ducula pacifica</i>											
<i>Cyanoramphus saisseti</i>	1			1	3	6	5	6	3		
<i>Chamosyna diadema</i>											
<i>Eunymphicus cornutus</i>							9	10	4	6	
<i>Chrysococcyx lucidus layardi</i>											
<i>Eudynamis taitensis</i>											
<i>Cacomantis flabelliformis</i>									?3	?1	
<i>Tyto alba</i> & cf <i>T. alba</i>									1?		
<i>Tyto letocarti</i> & cf <i>T. letocarti</i>					1	3		1		2	
<i>Ninox novaeseelandiae</i>					2	5	7	3	8	7	
<i>Aegotheles savesi</i>			1		5	9	20	?	21	8	1
<i>Eurostopodus exul</i>							1				
<i>Collocalia esculenta</i>											
<i>Collocalia</i> sp.	4	1	2		2	4	24	11		6	
<i>Todiramphus sanctus</i>											
Passerines	12	3	15	8	39	50	170	152	118	155	2
Total identified bird	22	4	29	11	67	119	311	274	219	259	5

Eurostopodus found in TP3 are a complete coracoid and a proximal femur. Both are very similar in size to *E. argus* (NMNZ 27371 [Museum of New Zealand Te Papa Tongarewa, Bird catalogue number]) and much smaller than those of *E. mystacalis*. Thus we follow Olson and Balouet (1989) in listing this taxon at the species level. The TP3 fossils are the first record of this taxon after the type specimen.

The New Caledonian owl-nightjar *Aegotheles savesi* is also known only by a single specimen, collected in 1880, but it was rediscovered in 1998, although it is very rare (Barré & Dutson 2002, Ekstrom *et al.* 2002). Balouet & Olson (1989) referred three fossil bones to this taxon. The

abundant bones in TP3 are thus a significant discovery that will allow morphometric comparison of this taxon to others in the genus.

Balouet & Olson (1989) reported the presence of a possible snipe, *Coenocorypha* species, based on three fragmentary bones. The 105 bones recorded in TP3 indicate that there was indeed a *Coenocorypha* species in New Caledonia, which was similar in size to the previous largest taxon in the genus *C. miratropica*, known as fossil from Fiji (Worthy 2003). Comparisons have not yet been made of these fossils with other members of the genus.

Of the other large extinct taxa reported by Balouet &



Figure 7. Bird bones. Above: lower leg bones of *Sylviornis neocaledoniae*, Cave B, The Crawl deposit. Below: A, Left humerus *Coturnix pectoralis*, Cave A, Testpit 3, 100–110 cm depth, scale bar 10 mm. B, Right tarsometatarsus, *Rhynochetos jubatus* (kagu), Cave A, The Crawl deposit, scale bar 50 mm. This is only slightly larger than a modern kagu tarsometatarsus NMNZ 22807. (Image: Jean-Claude Stahl and Raymond Coory, Te Papa.

Olson (1989) the extinct swamphen *Porphyrio kukweidei* was represented by just four bones. The extant swamphen *Porphyrio melanotus* is present down to 85 cm depth, and thus barely overlaps the depth distribution of its flightless congener *P. kukweidei*.

Balouet & Olson (1989) described an extinct kagu from bones at Pindai as *Rhynochetos orarius* on the basis that it was slightly bigger than *R. jubatus*. The difference is minor and of a scale often seen in populations of larger gruiforms, eg among *Gallirallus australis* in different locations in New Zealand (pers observ THW). The *Rhynochetos* specimens recovered by us differ little in size from NMNZ 22807, a recently collected specimen of *R. jubatus*, so *R. orarius* may be a slight geographical variant not worthy of specific status. A few kagu bones were found between 65 and 100 cm depth.

The now very rare, if not recently extirpated (Ekstrom *et al.* 2002), large rail of New Caledonia is the *Gallirallus* derivative, *Tricholimnas lafresnayanus*, which was present in low numbers in TP3, with two occurrences at shallow depths, long after the beginning of human presence in the site. Apart from the widespread *Gallirallus philippensis*, which had sparse occurrences in the site, another small galliralline rail that was previously unknown in New Caledonia, is represented by two bones. It is most similar to the Lewin's rail *Lewinia pectoralis* of Australia and like the stubble quail could be expected to appear in New Caledonia on grounds of geographical proximity.

Diurnal raptor bones are rare in the deposit. Balouet & Olson (1989) described two *Accipiter* species (*Accipiter quartus* and *A. efficax*) on the basis of fossils that were slightly larger than the extant *A. haplochrous* and *A. fasciatus*, respectively. Given the intraspecific variability in extant raptor size and taking into account that only a few *fasciatus* (none from New Caledonia) and few *haplochrous* specimens were examined, then these determinations are suspect. The cited unique feature of a proximal foramen in the femur of *haplochrous* would be expected among individual variation and the slenderness of the fossils would be expected on an allometric basis given its shorter length. In the fossil deposits of TP3, four bones of a large *Accipiter* that did not differ from reference *A. fasciatus* from New Caledonia (NMNZ 22840, 22999) were present. A coracoid with medial length of 41.8 mm was a bit larger and may be *A. efficax* if this is indeed a distinct taxon. A single, much smaller bone, a humerus TL=54.7 mm) was referred to *A. haplochrous* on the basis of size. In addition to *Accipiter* bones, an eagle is represented by a single phalanx and on the basis of size may refer to the extant *Pandion* sp. The whistling kite, *Haliastur sphenurus* was represented by a single left quadrate.

Balouet & Olson (1989) described the large pigeon *Caloenas canacorum*, and four bones in TP3 are likely to belong to this taxon. In addition to bones of the known columbid taxa of *Columba vitiensis*, *Ducula goliath*, *D. pacifica*, *Ptilinopus greyii* and *Chalcophaps indica*, there are

bones in TP3 from *Gallicolumba stairi* (1 bone), the extinct *G. longitarsus* (1 bone), another *Gallicolumba* sp. (9 bones) to which columbid sp. 2 (33 bones) may also belong, and at least one other small taxon (9 bones).

Bones of all three parrots recorded from New Caledonia are present in TP3. *Charmosyna* is known from just two specimens taken in 1859 but unconfirmed reports suggest it may yet survive (Barré & Dutson 2002, Ekstrom *et al.* 2002). The left ulna recorded in TP3 is referred to *Charmosyna* in the basis of its size. The other two parrots, *Eunymphicus cornutus* and *Cyanoramphus saisseti* are represented by good numbers of specimens and our examples from Pindai are the first fossil records for them in New Caledonia.

The owl bones present a problem as *Tyto letocarti* was described by Balouet & Olson (1989) on a left femur, two thoracic vertebrae, a left coracoid, a part scapula, a shaft of left humerus, and distal part of a juvenile femur. These indicate that the elements of the pectoral girdle are relatively smaller than expected from the femur and are similar to those of *Tyto alba* in size. Therefore the bones identified as cf *T. alba* from 85–110cm depth could equally well be *T. letocarti* which was identified in the same depth range from a much larger premaxilla, a distal humerus, and distal left femur. However, *Tyto* bones in upper levels are certainly *T. alba*.

The button quail of New Caledonia is now very rare (Barré & Dutson 2002, Ekstrom *et al.* 2002). Balouet & Olson (1989) found it to be common in an owl deposit in Gilles Cave at Boulouparis. It was the most abundant bird in the owl deposits of TP3. Of interest, is the observation that it was recorded sparsely from the surface layer in TP3 confirming its presence in TP1 and TP2 at shallow depths, so it survived until quite recently about Pindai and might do so yet.

Comparative notes on caves B, C, and F

The excavations in Cave B sampled two very different deposits. Testpits 1 and 2 were in essentially modern accumulations. There were few birds and rats dominated. All rat bones found in the areas with *Sylviornis* were clearly modern intrusive elements, probably the result of water, which periodically forms a lake in the cave, draining away and transporting small bones and other material downwards through the large and abundant gaps in the bone matrices seen in the undisturbed deposits of The Pocket and The Crawl.

In contrast, excavations in the Annexe and in the side areas of The Crawl and The Pocket sampled apparently prehuman deposits; sediments lacking any evidence of a human presence and holding comparatively abundant remains from large extinct taxa. Both were accumulations of primarily pitfall origin with large flightless taxa predominating, notably *Sylviornis* (Table 4). The small bird taxa found in Cave A were essentially absent.

Notable in these 'old' deposits were a single bone of *Anas gracilis*, and bones of the gruiforms *Tricholimnas*, *P. kukwiedei*, and *Rhynochetos*. The large megapode, *Megapodius molistructor*, described previously from Pindai 1 (Balouet & Olson 1989), was represented by a single coracoid. The non-avian fauna included, in addition to a few microbats, abundant *Pteropus vetulus* which must have had a colony in the cave, which with *Notopteris* and the swiftlets *Collocalia* species, contributed to the great depths of guano infill elsewhere in the cave.

The reptile fauna in the 'old' deposits includes bones of the crocodylian *Mekosuchus* and a large locally extinct varanid, in addition to the ubiquitous lizards. No bones of the terrestrial turtle *Meiolania* were found, although it had been reported previously on a single vertebra from a Pindai cave (Gaffney *et al.* 1984).

In Cave C the notable point about the fauna in TP1 is that *Rattus exulans* is common until 50 cm depth and rare occurrences in samples from lower down are probably material that fell from the unconsolidated baulks judging by their relatively unstained appearance, compared to most bones from the deeper layers, or perhaps the result of pre-excavation disturbance. In contrast fish bones are abundant to 100 cm depth, below which there are none that are clearly *in situ*. As the fish are almost certainly of anthropogenic origin, as in Cave A TP3, *Rattus exulans* appears to have arrived rather later than people. Humans probably brought in the turtle and snake bones as well, although sea snakes nest on the coast and the caves are only 100–200m from the shore. Bird bones are rare in the test-pit material. In contrast there are abundant lizard bones. These are relatively few until 100 cm, the point at which people arrived, and then are very abundant to the base of the deposit. Presumably they were accumulated by owls, although these layers lack the avian diversity seen in the owl deposits in nearby Cave A.

Cave F has dense shell middens in which fish bone is common, but remains of other vertebrates are scarce. *Rattus exulans* is common down to 20 cm depth and appears to have been absent below 30 cm, consistent with the pattern of comparatively late arrival seen in Caves A and C. Two bones of the frog *Litoria aurea*, assumed to have been introduced in European times, were found in spits at 50–70 cm depth. As the patterns of *Rattus* and fish bone distribution suggest the site of the excavation is not greatly mixed, the depth of these two bones might imply a prehistoric presence of this species or more likely a local event of bioturbation. Grant-Mackie *et al.* (2004) argued that *Litoria aurea* might have arrived prehistorically, according to the stratigraphy at Mé Auré Cave, but problems evident in the radiocarbon dating there need to be resolved before this proposition can be accepted.

Table 4. Significant faunal assemblages from Cave B excavations, by NISP.

Cave B sites–NISP	The Pocket + The Crawl	Annex TPA, surface	Annex TPA, 90–100	Annex TPA, 100–110	Annex TPA, 110–120	Annex Wall Pocket
<i>Megapodius molistructor</i>	1					
<i>Sylviornis neocaledoniae</i>	528		2	3	11	2
<i>Anas gracilis</i>	1					
<i>Accipiter efficax</i> (magn <i>A. fasciatus</i>)	4					
<i>Turnix varia novaecaledoniae</i>			1			
<i>Tricholimnas lafresnayanus</i>	3				2	
<i>Porphyrio kukwiedei</i>	4					
<i>Porphyrio melanotus</i>	1					
<i>Porzana tabuensis</i>	1					
<i>Rhynochetos orarius/jubatus</i>	10					
cf <i>Caloenas canacorum</i>	1					
<i>Eunymphicus cornutus</i>			1			
<i>Tyto letocarti</i>	1					
<i>Aegotheles savesi</i>	3					
<i>Collocalia</i> species	Many bones					
Passerines			1			
Other vertebrates						
<i>Mus musculus</i>			17			
<i>Rattus exulans</i>	Few, modern	5	24	few		
Microbats	small no.	3	few			Few
<i>Notopteris neocaledonica</i>	Few					
<i>Pteropus</i> cf <i>P. vetulus</i>	Many					
<i>Pteropus</i> sp. big	1					
Lizards	Many		few			Many
<i>Varanus</i>	Small no.			1		
<i>Mekosuchus inexpectatus</i>	62				1	4

RADIOCARBON DATING

Bone Pretreatment

The success of any bone radiocarbon determination is largely dependent on the preservation state of the sample (degree of contamination and degradation) and the pretreatment used to purify and isolate the bone protein. Therefore, the preservation of the bone protein was assessed for quality, prior to dating, using established criteria, including: %N of bone powder and $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, %N, %C and C/N of pretreated gelatin. Stable isotopes were measured at Soil, Plant and Ecological Sciences, University of Lincoln on a Dumas elemental analyser (PDZ Europa ANCA-GSL) interfaced to an isotope mass spectrometer (PDZ Europa 20–20).

Bulk bone nitrogen (%N) values were used to determine if sufficient protein remained for radiocarbon dating. Samples were selected from Cave A (TP3 and TP4), and Cave B. The results are shown in Table 5. Cave A bone ranged from 0.12–2.64 %N, with most falling below the 1%N level. Bones with low N are considered suspect for dating because gelatin ^{14}C results on low-protein bones

have been shown as problematic (Petchey 1998). Three samples were selected as suitable for radiocarbon analysis; from TP3 Spit 11 (Wk-14301), TP3 Spit 13 (Wk-14302), and TP3 Spit 18 (Wk-14089); with %N values of 1.04, 2.64 and 2.14 respectively. All material from Cave B was highly degraded and not selected for radiocarbon analysis.

Gelatin was extracted from the bones using a modified Longin method (Petchey & Higham 2000). First, the sample was cleaned, then decalcified in 2% w/v HCl at 4°C for 24 hours and rinsed with distilled water. Next, the acid insoluble collagen was gelatinised by heating it in weakly acidic water (pH = 3 at 90°C for 4 hours). The supernatant ('gelatin') was then removed and freeze-dried. Sub-samples of the gelatin were taken for stable isotope analysis and radiocarbon dating. The gelatin stable isotope results are shown in Table 5. Most well preserved archaeological bone protein has between 11 and 16%N, with an average 35%C and a C/N ratio range of 3.1–3.5 (van Klinken 1999: 691). The *Sylviornis* gelatin isotope results fall within these parameters.

Table 5. *Sylviornis* bone %N data and gelatin quality control data.

Location	Element id	%N bone	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C/N	N% gel	C% gel	Comments
Cave A								
TP3, Spit 11 (50–55cm)	Phalange	1.04	-19.8	9.61	3.46	11.7	34.7	Wk-14301:4073 \pm 53 BP
TP4 Spit 11 (50–55cm)	Sternum	0.12						Poorly preserved
TP3, Spit 12 (55–60cm)	Phalange	0.27						Poorly preserved
TP3, Spit 13 (60–65cm)	Pelvis	2.64	-20.12	8.73	3.32	13.1	37.3	Wk-14302:4743 \pm 44 BP
TP3, Spit 13 (60–65cm)	Claw	0.27						Poorly preserved
TP3 Spit 14 (65–70cm)	Long bone frag.	0.13						Poorly preserved
TP3 Spit 15 (70–75cm)	R tibia	0.12						Poorly preserved
TP3 Spit 17 (80–85cm)	Vertebra	1.74						Well preserved/Not dated
TP3 Spit 18 (85–90cm)	L femur	2.14	-20.15	8.89	3.20	14.5	39.8	Wk-14089:2875 \pm 43 BP
Cave B								
TCa	Phalange	0.41						Poorly preserved
TCb	L Femur	0.21						Poorly preserved
TCc	Long bone frag.	0.06						Poorly preserved
TPa	Long bone frag.	0.11						Poorly preserved
TPb	Long bone frag.	0.18						Poorly preserved
TPc	Long bone frag.	0.22						Poorly preserved

* Stable isotopes were measured at Soil, Plant and Ecological Sciences, University of Lincoln on a Dumas elemental analyser (PDZ Europa ANCA-GSL) interfaced to an isotope mass spectrometer (PDZ Europa 20–20). $\delta^{13}\text{C}$ values were measured relative to the VPDB standard and have errors of $\pm 0.1\text{‰}$. $\delta^{15}\text{N}$ values were measured relative to the AIR standard and have errors of $\pm 0.2\text{‰}$. In Cave B, TC=The Crawl, TP = The Pocket.

Charcoal and Shell Pretreatment

It is well documented that charcoal radiocarbon determinations may be affected by inbuilt age, which can result in errors of hundreds of years unless short-lived species (McFadgen 1982: 384) or twigs are selected (Anderson 1991: 781). New Caledonia has one of the oldest, most diverse and highly endemic floras in the Pacific but, unfortunately, it lacks an extensive comparative collection of wood (Wallace pers comm. 23/10/03). Therefore, none of the samples selected for dating could be positively identified to species. Research in the tropical Pacific (Allen and Wallace 2007) has demonstrated that un-calibrated wood charcoal samples identified to species can give radiocarbon results that are on average 64 ^{14}C yrs older than short-lived nutshell samples, and that some unidentified samples could be 300 or 400 years too old, especially in early sites where older wood sources were readily available. No twigs or seeds were identified in the Pindai samples. All charcoal samples were given an acid/base/acid pre-treatment to remove humic and fulvic acids derived from the decay of plants in the surface layer of the soil (Head 1987).

Given the limitations of available charcoal determinations several shell species were also selected for dating. These include *Anadara* sp. (Wk-15124) and *Spondylus* sp. (Wk-15125); both filter feeding shellfish, and *Strombus* sp. (ANU-12036 and ANU-12037) an algae grazer/herbivore (Beesley *et al.* 1998: 254, 278, 768). Filter feeding shellfish

usually consume suspended phytoplankton and dissolved inorganic carbon from seawater and are generally considered to be reliable for dating in open water situations such as that found at Pindai (Petchey *et al.* 2008). Herbivorous shellfish, on the other hand, may ingest detrital matter that, if derived from limestone bedrock, can influence the radiocarbon results (Dye 1994). Since a large proportion of the Nepoui Peninsula is Miocene age limestone (Lillie & Brothers 1970: 160) it is possible that dates of *Strombus* sp. shellfish could be affected.

Shell samples dated at the Waikato Radiocarbon Dating laboratory were tested for calcite re-crystallization prior to dating. Because *Spondylus* sp. shells naturally consist of both calcite and aragonite layers (Beesley *et al.* 1998: 278), the outer calcitic layer was removed as a precaution prior to dating. Samples dated at the Australian National University (ANU-12036 and ANU-12037) were not tested for re-crystallization. The outer surfaces of all shells were removed either by acid etching (Waikato) or with a dental drill (ANU).

Calibration and Results

Radiocarbon dating was carried out at three different laboratories: The Waikato Radiocarbon Dating laboratory, Beta Analytical and the Australian National University. Terrestrial samples were calibrated using SHCal04 (McCormac *et al.* 2004). Marine samples were calibrated using the Ma-

rineo4 curve of Hughen *et al.* (2004). A marine reservoir correction (ΔR) of -3 ± 9 yrs was used for New Caledonia in order to adjust for regional oceanic variation in radiocarbon (Petchev *et al.* 2008). All radiocarbon determinations were calibrated using the OxCal program v3.10 (Bronk-Ramsey, 2005).

The results reported here were taken only from the lower half of the human occupation sequence, because it was apparent in sorting faunal material that almost none from extinct taxa occurred higher than about 40 cm depth. The results, overall, show that the Pindai Caves were used by people during the first millennium of New Caledonian prehistory (Table 6, Figure 8), and probably later. Calibrated ages overlap considerably, but the span of the dated sequence probably does not extend beyond about 800 years. The oldest ages on charcoal (Beta-184382) and shell (Wk-15125) suggest that occupation in Cave A, testpit 3,

began in the interval 2600–2800 calBP (80–85 cm level). The 40–45 cm spit dates to about 2000–2300 calBP, and spits between (50–80 cm) have dates from about 2000 calBP to 2700 calBP. The spread of these latter dates and the clearly displaced older dates on *Sylviornis* bone (Wk-14301, Wk-14302) suggest that there might have been mixing of earlier cultural material as well as bone from a pre-human source in the 50–85 cm spits. In Cave A testpit 4, initial occupation was in the interval 2300–2500 calBP, and spits of 40–65 cm depth date to about 1800–2000 calBP.

FAUNAL OCCURRENCE IN TIME

As *Sylviornis neocaledoniae* is the most abundant and widespread of the fossil megafauna of New Caledonia it is important to be able to specify its distribution in time more accurately than merely within late Quaternary de-

Table 6. Radiocarbon determinations from Caves A, C and F, plus Balouet date, at Pindai, New Caledonia.

Lab. No. ¹	Material	Sq.	Provenance	CRA	$\delta^{13}C^2$	Cal range (95.4 %) AD
CAVE A						
Wk-15124	<i>Anadara</i> sp. shell	A/3	Spit 9 (40–45cm)	2536±36	1.26	2320–2110 BP
Beta-184383	Charcoal (unid)	A/3	Spit 9 (40–45 cm) B/C	2140±40	–24.8	2300–2270, 2160–1930 BP
Wk-14048	Broadleaf charcoal	A/3	Spit 11 (50–55 cm) C	2194±39	–25.7	2310–2230, 2210–1990 BP
Wk-14301	<i>Sylviornis</i> bone	A/3	Spit 11 C	4073±53	–20.1	4850–4750, 4700–4250 BP
Wk-14302	<i>Sylviornis</i> bone	A/3	Spit 13 C	4743±44	–20.4	5590–5410, 5490–5310 BP
Wk-14049	Broadleaf charcoal	A/3	Spit 14 (65–70 cm) C/D	2236±41	–25.3	2330–2050 BP
Beta-184382	Charcoal (unid)	A/3	Spit 16 (75–80 cm) C/E	2590±40	–26.1	2760–2460 BP
ANU-12036	<i>Strombus</i> shell	A/3	Spit 16 (75–80 cm) C/E	2310±190	0.0 est.	2400–1450 BP
Wk-15125	<i>Spondylus</i> sp. shell	A/3	Spit 17 (80–85cm)	2894±47	1.92	2770–2490BP
Wk-14050	Broadleaf Charcoal (single frag)	A/3	Spit 17 (85 cm) E	2307±39	–26.4	2350–2150 BP
Wk-14089	<i>Sylviornis</i> bone	A/3	Spit 18 (85–90 cm) E	2875±43	–20.4	3070–2790 BP
Beta-184384	Charcoal (unid)	A/4	Spit 9 (40–45 cm) B/D	2020±40	–25.4	2010–1810 BP
Wk-14046	Broadleaf charcoal and bark	A/4	Spit 13 (60–65 cm) F	1997±41	–25.5	2000–1810, 1800–1770, 1760–1740 BP
Wk-14047	Broadleaf charcoal	A/4	Spit 16 (75–80 cm) G	2385±40	–25.9	2490–2300, 2250–2150 BP
Beta-184385	Charcoal (unid)	A/4	Spit 18 (85–90 cm) G/H boundary	2380±40	–25.8	2490–2290, 2260–2150 BP
Balouet excavation						
Gif-6341	Charcoal (unid)	–		1720±70	0.0 est.	1730–1380 BP
CAVE C						
Beta-184379	Charcoal (unid)	C/1	55 cm	1640±40	–24.9	1570–1370 BP
ANU-12037	<i>Strombus</i> shell	C/1	Spit 17/18 (80–90 cm)	2470±180	0.0 est.	2650–1700 BP
Beta-184378	Charcoal (unid)	C/1	90–100 cm	2630±40	–25.9	2780–2670, 2650–2490 BP
CAVE F						
Beta-184380	Charcoal (unid)	F/1	40–50 cm	2240±40	–27.3	2340–2060 BP
Beta-184381	Charcoal (unid)	F/1	70–80 cm	2400±40	–24.8	2690–2640, 2500–2300, 2240–2180 BP

¹ Lab Code: Beta = Beta Analytic, USA; ANU = Australian National University, Australia; Gif = Gif sur Yvette, France; Wk = Waikato Radiocarbon Dating Laboratory, New Zealand.

² $\delta^{13}C$ value used to correct for vacuum line fractionation. Measured at the Waikato Stable Isotope Laboratory relative to the VPDB standard and has an error of $\pm 0.2\%$.

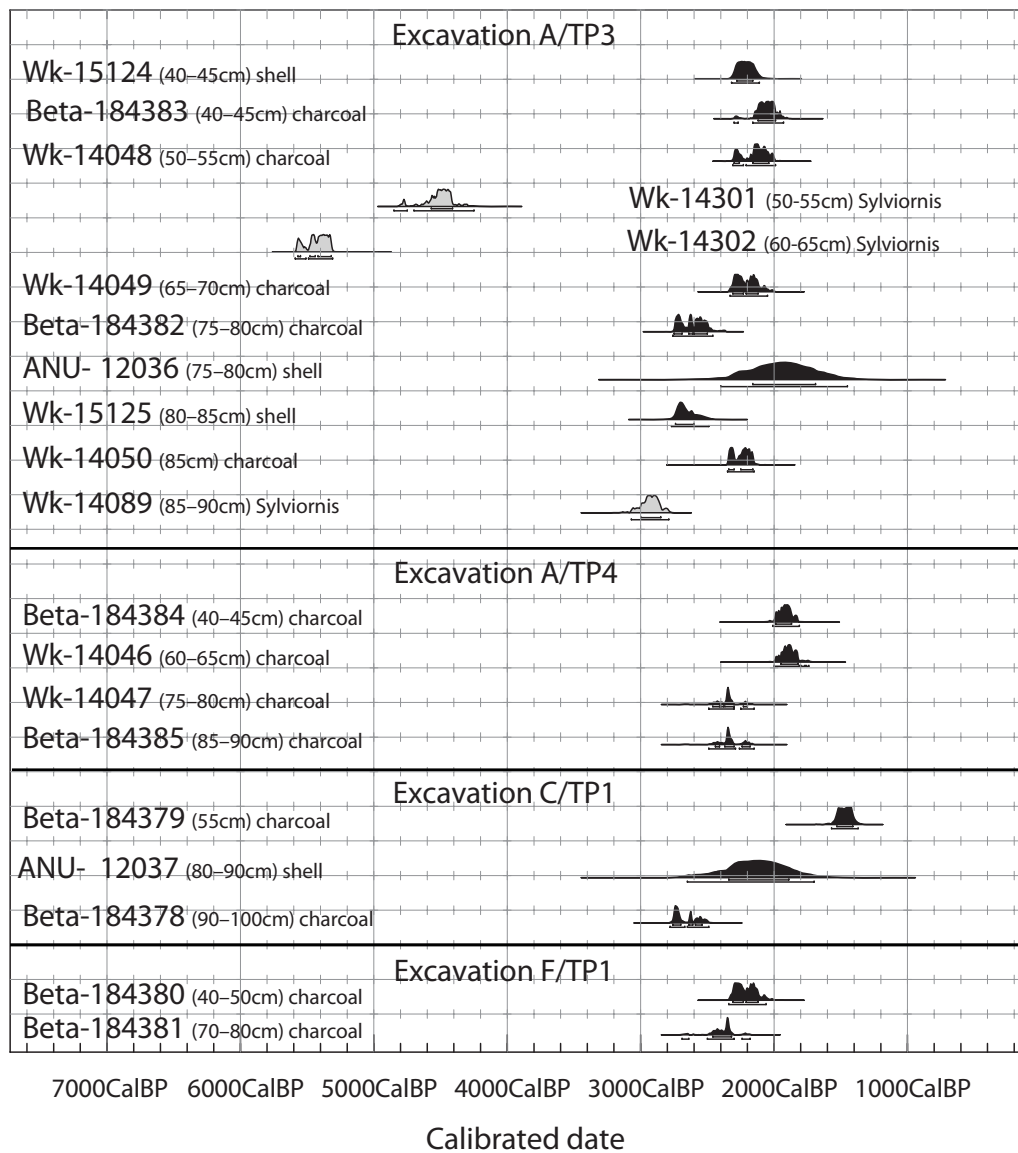


Figure 8: Radiocarbon dates from excavations at the Pindai Caves.

posits. Our three radiocarbon dates are the first directly upon *Sylviornis* bone. They show that the species survived into the late Holocene and up to the point of human arrival in New Caledonia. In the main excavation of interest here, TP3 in cave A, a date on a *Sylviornis* bone sample (Wk-14089) found just within level 85–90 cm, at the lowest level of occupation, almost overlaps at two sigma with archaeological dates from the same level and does certainly with the oldest dates on archaeological material in New Caledonia generally (Sand 1996). Yet, it is difficult to tell whether this is a significant result because *Sylviornis* samples from higher up in the strata (Wk-14301, Wk-14302) returned dates from more than a millennium prior to human arrival in New Caledonia. This suggests that some *Sylviornis* bone has been re-deposited into higher levels, possibly by bioturbation. Even so, *Sylviornis* bone is not

much more abundant in the pre-human levels than above them, and it is distributed consistently through most of the human occupation levels (Table 2) from 85 to 40 cm depth, with an outlying sample at 10–15 cm. Unfortunately, our attempts to find more *Sylviornis* bone samples with sufficient undegraded protein to return useful radiocarbon dates were unavailing (Table 5) so no unequivocal link can be made at Pindai between people and *Sylviornis* sp. That species, although the most common large vertebrate in the vicinity of the Pindai Caves (Table 4) might have disappeared after human occupation of New Caledonia generally but before habitation at Pindai in particular.

Of other taxa represented in Cave A, TP3, the flightless swamphen, *Porphyrio kukuwiedei*, occurs latest in levels dated 2800–2500 calBP on charcoal and on a wider range by shell date, ANU-12036. If the extinct kagu, *Rhyno-*

chetos orarius is distinguished validly from the extant *R. jubatus*, which is open to question (above), then it too extends up to levels dated about 2800–2500 calBP. A large extinct snipe, *Coenocorypha* sp. is represented into the beginning of the era of human occupation, possibly about 2800 calBP. The owls, *Tyto letocarti* and another similar to it, plus *Ninox novaeseelandiae*, may extend up to levels dated to about 2200 calBP. Most of a suite of extinct columbid species are represented only in pre-human levels (Table 2), but a species similar to *Gallicolumba stairii*, and the extinct pigeon *Caloenas canacorum*, occur close to or just within levels of human occupation.

On the basis of a single occurrence at 60–65 cm depth, *Mekosuchus* sp., may have overlapped with human occupation, but no varanid remains were found above the pre-human levels and no new material was recovered for the reported *Meiolania* sp. The case for human associations with these large reptiles in the Pindai Caves area remains weak, although *Mekosuchus*, at least, may have been reasonably common locally during the late Quaternary, according to the data from Cave B natural deposits (Table 4).

Turning to introduced taxa, it is not possible on the Pindai Caves data to resolve uncertainty surrounding the frog, *Litoria aurea*. Two isolated bones of *Litoria* were found at 50–70 cm in Cave F, where the midden is dated c. 2600–2000 BP, but *litoria* was absent in Cave A TP3 and TP4 where owls contributed large numbers of specimens of small taxa, and was only present in spit 1 of TP 1. Data are clearer on the introduction of *Rattus exulans*. In Caves A and C, bones of this species are virtually confined to the upper half of the cultural stratigraphy, possibly indicating a relatively late arrival in the area, around 2200 calBP, at least several hundred years after people. It is also possible that this distribution reflects the return of roosting barn owls, *Tyto alba*, the bones of which, also found pre-humanly, begin in the human occupation levels in Cave A, testpit 3, at about 40 cm depth (c.f. Grant-Mackie *et al.* 2003: 298 on data indicating sustained *Rattus exulans* predation at Mé Auré Cave after about 2300 bp).

DISCUSSION AND CONCLUSIONS

Consideration of evidence in Vanuatu, Fiji and Tonga allows the probability that an early anthropogenic impact on fauna will be demonstrated eventually in New Caledonia, but that should not be assumed in advance of robust evidence. It cannot be claimed that such evidence is apparent in data from the Pindai caves nor anywhere else in New Caledonia. Our new data from the Pindai Caves provide a much better record than existed previously of the diversity of non-passerine birds and other vertebrates that existed in this district of New Caledonia during the Holocene era. That is especially so of the approximately 20 taxa that are locally or globally extinct, for which our research provides some new records and additional support for older records, in some cases altering the known distribution in

time. Yet, it is not possible to deliver conclusive statements about the relationships of these taxa, and their disappearance, to human habitation, which was the main objective of our project.

The difficulties of work on ancient tropical faunas are well-known and tenacious. Caves are subject to rock-fall and the debris is often loose and unstable providing conditions in which bones and cultural material can be re-deposited at lower levels. In sink-holes, especially, water flow and ponding moves small bones, charcoal and shell up and down and from place to place. Landcrabs and other burrowing animals are common and similarly capable of moving material in all directions. Surviving bone seldom provides suitably undegraded protein for radiocarbon dating, forcing chronology to rely upon indirect radiocarbon dating of charcoal and marine shell. Contemplation of these problems recommends great caution in interpreting data pertinent to questions of anthropogenic influence in extinction.

In considering the data from Cave A, the compositional difference in stratigraphy between TP3 and TP4, viewed against the overlap of extinct taxa with evidence of human habitation, might be thought instructive. In TP4, where the stratigraphy appears very little disturbed, only a few pieces of *Sylviornis* bone extend into human occupation levels. In TP3, where the sedimentary stratigraphy is interrupted by tumbled rocks and boulders, some being roof-fall plates and others originating evidently in the talus slope below the pitfall cave entrance, relatively more *Sylviornis* bone, and also bone from a number of other extinct taxa, extend well into human occupational levels. Equally, it is possible that the difference is mainly chronological. The earliest occupation level in TP4 is possibly several hundred years younger than in TP3, in which case much of the faunal depletion that is seemingly recorded in the TP3 sequence might have occurred before deposition of human occupation material in TP4. However, as age and depositional affects cannot be clearly separated on current data, it cannot be argued that the weight of evidence favours a broad coincidence of extinction with human settlement, except in one respect.

Whether or not most of the extinct taxa disappeared as the result of human activity, the evidence from Cave A shows that most were represented by greater density of bone fragments in the levels immediately preceding those representative of human occupation. Unfortunately, the precise age of the immediately pre-human levels is unknown, because there was no material in them suited to radiocarbon dating. However, if it is assumed that our mid-Holocene dates on *Sylviornis* represent material from beneath the cultural levels, and probably from the relatively dense bone deposits immediately below cultural strata, then no great elapse of time was involved in the transition from pre-human to occupational levels. Therefore, even if the evidence within the human occupational levels is for the most part the result of re-deposition rather than actual

co-existence, there was a suite of Quaternary fauna that survived until the late Holocene, and probably very close to the time of human arrival if not until actually within it.

More specifically, it can be concluded that: (1) *Sylviornis* was sufficiently abundant locally to have coexisted for some years with human habitation. Stratigraphic evidence and one radiocarbon date support the proposition that this occurred but they cannot do so definitively because of problems of disturbance and chronology; (2) most of the other extinct avifaunal taxa probably disappeared locally around the time of human arrival, given the TP4 stratigraphic distribution, or survived for some years in coexistence if the TP3 stratigraphic distribution is preferred, and (3) there is no case as yet for human coexistence with, or human impact upon, the large reptilian taxa: *Mekosuchus* sp., *Varanus* sp., and *Meiolania* sp. The extent of anthropogenic faunal extinction in New Caledonia thus remains largely uncertain still, and much more fieldwork and analysis, including at the Pindai Caves, is needed to resolve the issues convincingly across a range of taxa. Fortunately, radiocarbon dating of bone is continuing to improve and new techniques of ultrafiltration of gelatin samples may soon reach the stage where many samples now rejected as poor, as were most of ours (Table 5), will be suited to dating. Numerous dates on bones of extinct taxa are likely to prove the most reliable method of distinguishing contemporaneity, or otherwise, with human habitation.

Acknowledgements

To the Northern province President Paul Néaoutiyne and the cultural authorities for authorisation to undertake excavations in Pindai. To the customary authorities of the tribes of the Poya and Pouembout region, for their agreement to allow the excavations. To National Geographic Society, the Service des Musées et du Patrimoine (Département Archéologie) and ANU for financial and material assistance. The fieldwork occupied a total of 30 person-weeks by the following people: Professor Atholl Anderson, Ms Rosanne Anderson (Australian National University, Canberra), Dr Christophe Sand, Mr David Baret, and Mr Jacques Bolé (Département Archéologie, Service Territorial des Musées et du Patrimoine, Noumea), Dr Fiona Petchey (Radiocarbon Laboratory, University of Waikato, New Zealand) and Mr Trevor Worthy and Ms Jenny Jones (Palaeofaunal Surveys, Masterton, New Zealand). Dr Rod Wallace (Auckland University) identified the charcoal used for radiocarbon dating.

References

- Allen, M.S. & Wallace, R. 2007. New evidence from the East Polynesian gateway: Substantive and methodological results from Aitutaki, southern Cook Islands. *Radiocarbon*, 49: 1–17.
- Anderson, A.J. 1989. *Prodigious Birds: Moas and Moa-hunting in Prehistoric New Zealand*. Cambridge: Cambridge University Press.
- Anderson, A.J. 1991. The chronology of colonisation in New Zealand. *Antiquity*, 65: 767–795.
- Anderson, A.J. 2000. Defining the period of moa extinction. *Archaeology in New Zealand*, 43: 195–200.
- Anderson, A.J., Ayliffe, L., Questiaux, D., Sorovi-Vunidilo, T., & Worthy, T. 2001. The terminal age of the Fijian megafauna, in A.J. Anderson, I. Lilley, & O'Connor (eds.) *Histories of Old Ages: Essays in Honour of Rhys Jones*. Canberra: Pandanus Books, 251–264.
- Balouet, J.-C. 1984. Paléothologie des vertébrés terrestres de Nouvelle-Calédonie et paléogéographie du pacifique sud-ouest. Paris: Université P. et M. Curie, Paris VI. These de 3^e cycle.
- Balouet, J.-C. 1987. Extinctions des vertébrés terrestres de Nouvelle-Calédonie. *Mémoires de la Société Géologique de France (NS)*, 150: 177–183.
- Balouet, J.-C. 1991. The fossil vertebrate record of New Caledonia, in P. Vickers-Rich, J.M. Monaghan, R.F. Baird & T.H. Rich (eds.), *Vertebrate Palaeontology of Australasia*. Melbourne: Monash University, 1383–1409.
- Balouet, J.-C. & Buffetaut, E. 1987. *Mekosuchus inexpectatus*, n. g., n. sp., Crocodilien nouveau de l'Holocène de Nouvelle Calédonie. *Comptes Rendus de l'Académie des Sciences, Series II, Mécanique, Physique, Chimie, Sciences de l'Université, Paris* 304 : 853–856.
- Balouet, J.-C. & Olson, S.L. 1989. *Fossil Birds from Late Quaternary Deposits in New Caledonia*. Washington D.C.: Smithsonian Contributions to Zoology 469: 1–38.
- Barré, N. & Dutson, G. 2002. *Liste Commentée Oiseaux de Nouvelle-Calédonie. Secrétariat d'Etat à l'Outremer Service des Affaires Culturelles, Nouvelle-Caledonie*, 48 pp.
- Bedford, S. 2006. *Pieces of the Vanuatu Puzzle: Archaeology of the North, South and Centre*. Canberra: Australian National University, Terra Australis 23.
- Beesley, P.L., Ross G.J.B., & Wells A. (eds), 1998. *Mollusca: the Southern Synthesis. Fauna of Australia. Vol. 5*. Melbourne: CSIRO Publishing.
- HYPERLINK <http://www.rlaha.ox.ac.uk/oxcal/ref.htm#bronk95>
Bronk-Ramsey C. 1995. Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program *Radiocarbon*, 37: 425–430.
- HYPERLINK <http://www.rlaha.ox.ac.uk/oxcal/ref.htm#bronko1>
Bronk-Ramsey C. 2001. Development of the Radiocarbon Program OxCal, *Radiocarbon*, 43: 355–363.
- Brook, B.W. & Bowman, M.J.S. 2002. Explaining the Pleistocene megafaunal extinctions: models, chronologies and assumptions. *Proceedings of the National Academy of Sciences*, 99: 14624–27.

- Dye, T. 1994. Apparent ages of marine shells: Implications for archaeological dating in Hawaii. *Radiocarbon*, 36: 51–58.
- Ekstrom, J.M.M., Jones, J.P.G., Willis, J., Tobias, J., Dutton, G., & Barré, N. 2002. New information on the distribution, status and conservation of terrestrial bird species in Grande Terre, New Caledonia. *Emu*, 102: 197–207.
- Gaffney, E.S., Balouet, J.C. & de Froin, F. 1984. New occurrences of extinct meiolaniid turtles in New Caledonia. *American Museum Novitates*, 2800: 1–6.
- Grant-Mackie, J.A., Bauer, A.M., & Tyler, M.J. 2004. Stratigraphy and herpetofauna of Mé Auré Cave (site WMD007), Moin-dou, New Caledonia, in C. Sand (ed.), *Pacific Archaeology: Assessments and Prospects*. Noumea : Le Cahiers de l'Archéologie en Nouvelle-Calédonie, 15: 295–306.
- Head, M.J. 1987. Categorisation of organic sediments from archaeological sites, in W.R. Ambrose & J.M.J. Mummery (eds.), *Archaeometry: Further Australian Studies*. Canberra: Australian National University, 143–159.
- Higgins, P.J. (ed.) 1999. *Handbook of Australian, New Zealand & Antarctic birds. Parrots to Dollarbird*. Volume 4. Melbourne: Oxford University Press.
- Holdaway, R.N. & Jacomb, C. 2000. Rapid extinction of the moas (Aves: Dinornithiformes); model, test and implications. *Science*, 287: 2250–54.
- Hughes, K.A., Baillie, M.G.L., Bard, E., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Kromer, B., McCormac, G., Manning, S., Bronk-Ramsey, C., Reimer, P.J., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., & Weyhenmeyer, C.E. 2004. Marine 04 Marine Radiocarbon Age Calibration, 0–26 CAL KYR BP. *Radiocarbon*, 46: 1059–1086.
- Lillie, A.R. & Brothers, R.N. 1970. The geology of New Caledonia. *New Zealand Journal of Geology and Geophysics*, 13: 145–183
- Martin, P.S. & Steadman, D.W. 1999. Prehistoric extinctions on islands and continents, in R.D.E. McPhee (ed.) *Extinctions in Near Time: causes, contexts and consequences*. New York: Kluwer Academic, 17–55.
- McCormac, F.G., Hogg, A.G., Blackwell, P.G., Buck, C.E., Higham, T.F.G. & Reimer, P.J., 2004. HCAL04 Southern Hemisphere Calibration, 0–11.0 CAL KYR BP. *Radiocarbon*, 46: 1087–1092.
- McCulloch, B., & Trotter, M. 1975. The first twenty years. Radiocarbon dates from South Island Moa hunter sites, 1955–74. *New Zealand Archaeological Association Newsletter*, 18: 2–17.
- McFadgen, B.G. 1982. Dating New Zealand archaeology by radiocarbon. *New Zealand Journal of Science*, 25: 379–392.
- Mead, J., Steadman, D., Bedford, S., Bell, C. & Spriggs, M. 2002. New extinct Mekosuchine crocodile from Vanuatu, South Pacific. *Copeia* 2002: 632–641.
- Molnar, R.E., Worthy, T.H., & Willis, P.M.A. 2002. An extinct Pleistocene endemic mekosuchine crocodylian from Fiji. *Journal of Vertebrate Paleontology*, 22: 612–628.
- Petchey, F. 1998. Radiocarbon Analysis of a Novel Bone Sample Type: Snapper and Barracouta Bone from New Zealand Archaeological Sites. Unpublished D. Phil thesis, Hamilton: University of Waikato.
- Petchey, F., & Higham, T.F.G. 2000. Bone diagenesis and radiocarbon dating of fish bone at the Shag River Mouth site, New Zealand. *Journal of Archaeological Science*, 27: 135–150.
- Petchey, F., Anderson, A., Zondervan, A., Ulm, S. & Hogg, A., 2008. New marine ΔR values for the South Pacific Subtropical gyre region. *Radiocarbon* 50: 373–397.
- Pregill, G.K. & Dye, T. 1989. Prehistoric extinction of giant iguanas in Tonga. *Copeia* 1989: 505–508.
- Pregill G.K., & Worthy, T.H. 2003. A new iguanid lizard (Squamata, Iguanidae) from the late Quaternary of Fiji, Southwest Pacific. *Herpetologica* 59: 57–67.
- Sand, C. 1996. *Le Début du Peuplement Austronésien de la Nouvelle-Calédonie: Données archéologiques récentes*. Noumea: Le Cahiers de l'Archéologie en Nouvelle-Calédonie, 6.
- Sand, C., Bolé J., & Ouetcho, A. 2003. Prehistory and its perception in a Melanesian Archipelago: the New Caledonia example. *Antiquity*, 77: 505–519.
- Steadman, D.W. 1995. Prehistoric extinctions of Pacific Island birds: biodiversity meets zooarchaeology. *Science* 267: 1123–1131.
- Steadman, D.W. 2006. *Extinction and Biogeography of Tropical Pacific birds*. Chicago: University of Chicago Press.
- Steadman, D.W., Pregill, G., & Burley, D.V. 2002a. Rapid prehistoric extinction of iguanas and birds in Polynesia. *Proceedings of the National Academy of Sciences, USA*, 99: 3673–3677.
- Steadman, D.W., Plourde, A., & Burley, D.V. 2002b. Prehistoric butchery and consumption of birds in the kingdom of Tonga, South Pacific. *Journal of Archaeological Science*, 29: 571–584.
- van Klinken G.J. 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurement. *Journal of Archaeological Science*, 26: 687–695.
- Worthy, T.H., Anderson, A.J. & Molnar, R.E. 1999. Megafaunal expression in a land without mammals – the first fossil faunas from terrestrial deposits in Fiji (Vertebrata: Amphibia, Reptilia, Aves). *Senckenbergiana biologica*, 79: 237–242.
- Worthy, T.H., Walter, R., & Anderson, A.J. 1998. Fossil and archaeological avifauna of Niue Island, Pacific Ocean. *Notornis*, 45: 177–190.
- Worthy, T. H., 2000. The fossil megapodes (Aves: Megapodiidae) of Fiji with descriptions of a new genus and two new species. *Journal of the Royal Society of New Zealand*, 30: 337–364.
- Worthy, T.H. 2001a. A new species of *Platymantis* (Anura: Ranidae) from Quaternary deposits on Viti Levu, Fiji. *Paleontology*, 44: 665–680.
- Worthy, T.H. 2001b. A giant flightless pigeon gen. et sp. nov. and a new species of *Ducula* (Aves: Columbidae), from Quaternary deposits in Fiji. *Journal of the Royal Society of New Zealand*, 31: 763–794.
- Worthy, T.H. 2003. A new extinct species of snipe *Coenocorypha* from Viti Levu, Fiji. *Bulletin of the British Ornithological Club*, 123: 90–103.