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Manufacture and use of hook-tools by New Caledonian crows

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Tool behaviour in wild birds has been described as mostly stereotyped[1,2], and tool manufacture involves little modification of material[3–5]. Here I report in New Caledonian crows *Corvus moneduloides* the manufacture and use of two different types of hook tool to aid prey capture: hooked-twig and stepped-cut barbed pandanus leaf. Crow tool manufacture had three features new to tool use in free-living nonhumans: a high degree of standardization, distinctly discrete tool types with definite imposition of form in tool shaping, and the use of hooks. These features only first appeared in the stone[6] and bone[7] tool-using cultures of early humans after the Lower Palaeolithic[6,7], which indicates that crows have achieved a considerable technical capability in their tool manufacture and use.

Crows are forest birds endemic to New Caledonia, where they are omnivores and live in family groups[8]. Like Corvids generally[9–14] they are resourceful, for example manipulating twigs with their bills to search for prey in dead wood[15] and dropping *Aleurites moluccana* nuts onto rocks to get their seeds. In rainforest on Pic Ningua (950–1,300 m above sea level), I observed non-banded, non-aged and non-sexed crows between November 1992 and March 1995 in all months except January. On 52 different occasions between 07:00 and 15:30 I observed tool behaviour by one or more (up to four) birds. Observations were made of four crows manufacturing tools and 68 crows using or carrying tools. On average, three birds (range, 1–9) were present on each occasion. Crows used tools in holes in living and dead wood (Fig. 1*a*, *b*) and among the bases of palm and *Freycinetia longispica* (Fig. 1*c*) leaves, where they captured unidentified prey. I found larvae, spiders, millipedes, weevils, cockroaches, flatworms, amphipods, isopods, centipedes and earwigs at similar search sites.

Crows searched many sites in different trees with the same tool. The longest period I could stay in visual contact with a tool-using bird was 30 min. I could not establish tool life because birds changed foraging localities frequently, taking their tools with them. Tools I collected from crows I frightened away or those they dropped in my presence were of fresh plant material.

Between foraging episodes, crows often transferred their tools to their feet or placed them in a secure position on their perch, retrieving them with their bills before departing (Orenstein[15] observed a bird put down a tool-like object, then pick it up soon after and fly off with it). Two birds changed trees after putting down their tools, returning within minutes to retrieve them. When feeding on prey, birds left tools in search sites or transferred them to their feet. In the breeding season I observed an adult with both

TABLE 1 Data on stepped-cut tool cutouts from *Pandanus* spp. trees at two areas on Pic Ningua, and one at Mt. Cindoa.

Tree no.	No. cutouts collected per tree	No. cutouts estimated as present	Mean cutout length (cm) for each area/ s.e.m./(range)	Mean no. of steps per cutout for each area/ s.e.m./(range)
Pic Ningua (area 'A')				
1	13	17		
2	23	30		
3	18	21	14.95/0.172/	3.10/0.037/
4	37	53	(10.6–22.2 cm)	(2–5 steps)
5	14	15		
Pic Ningua (area 'B')				
6	17	18		
7	52	72		
8	23	28	16.65/0.170/	3.11/0.037/
9	51	65	(12.1–24.9 cm)	(2–6 steps)
10	14	14		
Mt Cindoa				
11	9	9		
12	10	10		
13	5	5	20.65/0.644/	3.49/0.102/
14	7	7	(11.8–40.0 cm)	(2–5 steps)
15	12	13		

Pandanus spp. trees can be single or multitrunked, with long, narrow leaves at the top of a trunk that spiral outwards and upwards around it. Trees 12 and 15 were double-trunked. I chose trees from two separate areas on Pic Ningua (minimum distance separating the trees between the two areas was 900 m) to try and detect differences in the structure of tools manufactured by crows. I chose a tree from a distance without knowledge of the number or shape of cutouts on it, and finally selected it if sufficient cutouts were present (> 9 at Pic Ningua; > 4 at Mt Cindoa). The five selected trees within each area were widely distributed. I removed as many undamaged cutouts as possible from living leaves (cutouts were mostly near leaf bases). I measured cutout length (length of missing leaf edge) off the (undried) cutout shape I outlined on paper. Mean cutout length was different between all three areas when the significant variation between trees within each area was removed (Nested ANOVA, $F = 21.88$, d.f. $= 2$, $P \ll 0.05$; and $F = 4.37$, d.f. $= 12$, $P \ll 0.05$, respectively). Available space (estimated number of cutouts present) on leaf edges of individual trees at Mt Cindoa and Pic Ningua was not associated with the mean cutout lengths for the trees (Pearson correlation coefficient, $r = -0.0682$, $n = 5$, $P \gg 0.05$, and $r = 0.165$, $n = 10$, $P \gg 0.05$, respectively). The number of stepped-cuts (the square root normalized data) on cutouts was different between Pic Ningua (data for areas A and B combined) and Mt Cindoa when cutout length was accounted for (ANCOVA, F (area) $= 9.72$, d.f. $= 1$, $P \ll 0.05$; and F (length) $= 3.29$, d.f. $= 1$, $P > 0.05$).

FIG. 1 Drawings of tool-using behaviour by *C. moneduloides*. Birds are shown searching for prey with hooked-twig tools (held angleways in their bills[15]) in the base of *F. longispica* leaves (*c*) and in the broken-off ends of dead branches (*a* and *b*). A stepped-cut tool is shown held longways in a crow's bill (*d*).

food and a tool in its bill land next to a juvenile, transfer the tool to its feet, feed the juvenile, then pick up the tool and fly off with it.

I collected two types of tool from crows: hooked-twig (Fig. 2*c–j*), and stepped-cut tools (Fig. 3*B*, *b–j*). Hooked-twig tools were manufactured from living secondary twigs. All were stripped of leaves, and usually bark, and had a hook (a section of primary twig) on their wide ends. Stepped-cut tools were cut out along *Pandanus* spp. leaf edges. They had tapered shapes making them pointed but sturdy, and sharp and rigid barbs along their uncut edges which always faced upwards from the narrow ends. Tapered shapes seemed appropriate when birds searched in sites holding these tools longways (Fig. 1*d*). I only observed birds using the hook end of hooked-twig tools, and the narrow end of stepped-cut ones, in search sites; collected tools I visually inspected were dirty or worn only at the working tips.

Rapid back and forth movements[15] of both tool types were used where prey were under detritus (Fig. 1*a*). I observed material being hooked out of these sites. Slow and careful movements were used to obtain prey from bases of leaves and holes where it was possible that crows could see their prey (Fig. 1*b, c*).

I did not observe stepped-cut tool manufacture, but from cutouts I inspected on leaves (Fig. 3) crows cut tools out neatly. Almost-completed tools on leaves (Fig. 3) and associated bill marks indicated birds did this working from the narrow to the wide end. I observed birds manufacture and complete four hooked-twig tools before their use. Birds removed secondary twigs along with part of the primary twig (Fig. 2*b*). They then flew to perches and transferred them to their feet and spent some minutes working on the hook ends with their bills (I observed hooks on the completed tools). Finally they removed the leaves, and usually bark, from the twig. The numbers of cutouts on tree leaves at Pic Ningua indicated that stepped-cut tools were manufactured there in large numbers (Table 1). Thirty-eight of the 55 tools that I saw being carried by crows and could positively identify were hooked-twig ones.

Tool use by crows was widespread as I collected tools from birds at three other forest sites (Figs 2, 3). These included unhooked-twig tools and an untapered strip of *Pandanus* sp. leaf-edge that birds used in Rivière Bleue Park. The lengths of stepped-cut tool cutouts differed between three areas: two areas at Pic Ningua (Table 1), and one at Mt Cindoa (Table 1). Whereas cutouts had strongly discrete shapes within areas at Pic Ningua, their lengths and the number of steps varied. This indicated that tool standardization[16] was not constrained by raw material or manufacture technique.

That crows used hooks is implied by the manufacture and use of two different tool types that incorporated hooks in a way that should aid prey capture by allowing birds to hook material or prey from search sites. Hook use suggests an appreciation of tool

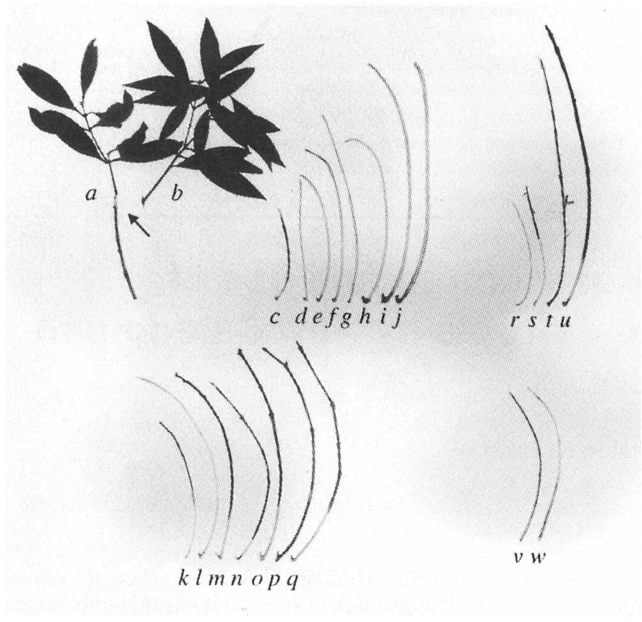

FIG. 2 Twig tools collected from *C. moneduloides* from 1993–95 at Pic Ningua and three other forest sites: Mt Cindoa (6 km from Pic Ningua; 1,100–1,250 m above sea level) and Rivière Bleue Park (60 km southeast of Pic Ningua; 150–200 m) on the mainland, and Maré Island (110 km from the mainland; 0–100 m; crows introduced around 1900). Birds searched for prey with the bottom ends of the tools, which are all hooked except for tools labelled *r–t* and *v–w*. Using plant material from *Osmanthus austrocaledonicus* I show how one crow (in tall shrubby vegetation bordering the rainforest) removed twigs for tool manufacture. It removed the secondary twig (*b*) from the primary one (*a*; removal position arrowed) with a 'nipping' cut at the intersection of the twigs. This resulted in a 'hook' (the nipped-out section of the primary twig; twigs I broke off did not have hooks) on the secondary twig that needed shaping to match the ones on tools I collected from birds. Pic Ningua tools (*c–j*) were manufactured from *O. austrocaledonicus* (*c*), and *Elaeocarpus dognyensis* (*d–j*). Mt Cindoa tools (*k–q*) were manufactured from an undescribed *Elaeocarpus* sp. (*k–m*); an unidentified species (*n*), and possibly Rubiaceae (*o–q*). Rivière Bleue Park tools (*r–u*) were manufactured from *Gymnostoma webbiani* (*r–s*), *Greslania rivularis* (*t*, a bamboo flower stem), and Rubiaceae (*u*). Maré Island tools (*v–w*) were manufactured from Oleaceae or Verbenaceae. Tool length (measured on a straight line between both ends of a tool) and shaft diameter (taken a few mm from the wide end) were not different between the four sites (Kruskal–Wallis one-way non-parametric ANOVA, d.f. = 20, $F = 0.53$, $P = 0.67$, and one-way ANOVA, $F = 0.83$, $P = 0.50$, respectively). For scale, tool *i* is 19.2 cm in length.

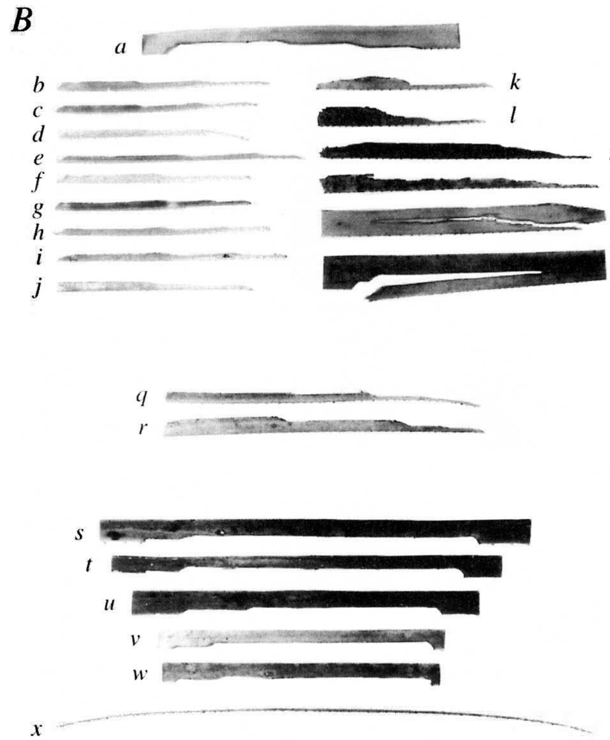

FIG. 3*A*, An almost-completed stepped-cut tool on a *Pandanus* sp. leaf (leaf width at the cutout is ~7.5 cm) from the leaf underside looking skywards (leaf tips are at the top of the photograph). All cutouts I observed had their narrow ends oriented towards the trunk. *B*, Stepped-cut tools collected from *C. moneduloides* and leaf material collected from *Pandanus* spp. trees at Pic Ningua and two other forest sites (Mt Cindoa, and Rivière Bleue Park) from 1993–95. Leaf-edge barbs (bottom sides) on material *a–r* face left, and rightwards on *s–x* (the narrow ends on some tools bowed when drying). Pic Ningua material: an example of a stepped-cut tool cutout (*a*); stepped-cut tools (all 3-stepped) collected from crows (*b–j*; mean length, 14.90 cm; s.e.m. = 0.410); 3 completed tools (*k–m*) I found under one tree (respective cutouts were on its leaves), and two almost-completed ones on its leaves (*n*, *o*; tool *n* was removed from the leaf as it was just attached), which were noticeably misshapen compared to tools *b–j*; an example (*p*) of leaf-edge strips which were commonly cut (bill marks were often present) and ripped (always towards the leaf bases) on leaves at Pic Ningua and Mt Cindoa, but less so at the Rivière Bleue Park. Mt Cindoa material: the tool I collected from a crow (*q*; length, 21.4 cm) was similar in shape to the one I found among leaves in a tree there (*r*; length, 22.0 cm). Rivière Bleue Park material: five cutouts (all 2-stepped) I collected off three trees (*s–w*; mean length of missing leaf edge = 19.62 cm, s.e.m. = 1.106); an unstepped-cut tool I collected from a crow (*x*; length = 37.8 cm; working tip at left).

functionality[17], and a tool kit suggests different tools for different tasks[18].

Crow tool manufacture had three features new to tool use in free-living nonhumans, and that only first appeared in early human tool-using cultures after the Lower Palaeolithic[6,7]: a high degree of standardization, distinctly discrete tool types with definite imposition of form in tool shaping, and the use of hooks. □

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Development of identical orientation maps for two eyes without common visual experience

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In the mammalian visual cortex, many neurons are driven binocularly and response properties such as orientation preference or spatial frequency tuning are virtually identical for the two eyes[1]. A precise match of orientation is essential in order to detect disparity and is therefore a prerequisite for stereoscopic vision. It is not clear whether this match is accomplished by activity-dependent mechanisms together with the common visual experience normally received by the eyes[2,3], or whether the visual system relies on other, perhaps even innate, cues to achieve this task[4–7]. Here we test whether visual experience is responsible for the match in a reverse-suturing experiment in which kittens were raised so that both eyes were never able to see at the same time. A comparison of the layout of the two maps formed under these conditions showed them to be virtually identical. Considering that the two eyes never had common visual experience, this indicates that correlated visual input is not required for the alignment of orientation preference maps.

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