Supporting Online Material for

The Ecological Significance of Tool Use in New Caledonian Crows

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Materials and Methods

Study site

Fieldwork was conducted from October 2006 to February 2007 in our focal study site in dry forest habitat (Tabou and Taro valleys) in the Parc Provincial de Gouaro-Déva (21°33' S, 165°19' E), on the central west coast of New Caledonia, South Pacific [see fig. S3 in (*S1*)].

Crow samples

Our sample comprises 22 New Caledonian crows (*Corvus moneduloides*) (hereafter NC crows), of which 13 were male and 9 female; 6 were adults, 7 immature, and 9 nestlings and juveniles (grouped here as 'juveniles'). Older birds were trapped with whoosh nets (*S2*), while some juveniles were sampled when they were still in, or near, the nest (4 birds).

Crows were sexed with standard molecular techniques, using blood samples stored in ethanol (*S2*). The gape colouration of corvids typically changes from pink to black over the first few years of life [(*S3*); for NC crows, pers. obs.]. On trapping crows, we examined and photographed gapes, which allowed us to distinguish between three age classes: nestlings and juveniles (nutritionally dependent on parents; some of the older 'juveniles' in our sample had started their first moult) have gapes that are ≤ 10% black; immature individuals (between *ca.* 1–2 years of age; nutritionally independent but probably not yet fully-proficient tool users) have 30–80% black colouration; and adults (reproductively mature and capable tool users) have 90–100% black colouration. While there may be some variation in how gape colouration changes with time, especially in relation to social status [(*S3*); pers. obs.], we believe our classification with just three basic categories was sufficiently robust for the purposes of the present paper [especially since we could corroborate our scoring with additional pieces of information for some individuals; e.g., breeding status or year of fledging; see (*S1*)].

For each trapped crow, small feather samples (*ca.* 2 × 2 cm) were clipped with surgical scissors, and subsequently stored individually in sealed polyethylene specimen bags. In NC crows, moult of flight feathers is descendent and complete (unpubl. data), beginning with the innermost primaries and tail feathers, and the outermost secondaries. We therefore sampled feathers that represented different stages in the annual moult cycle—the tips of the third primary, third secondary and third tail feather of either body side—and took an additional chest-feather sample, which was likely to integrate tissue grown during an extended time period. Where available (n = 13 crows), a fifth sample (primary base) was included in analyses to provide an additional level of temporal resolution. Juveniles

required faster processing in the field to avoid undue disturbance, so we took fewer samples for analysis: thus, we used for three subjects only primary samples (two feathers with tips and bases, respectively), and for one bird only one primary tip and a chest-feather sample. This was unlikely to bias our estimates as juveniles grow their first set of feathers at roughly the same time, so between-feather variation in isotopic ratios is negligible. The number of feather samples analysed per crow was 4 or 5 (apart from one nestling with only two samples; see above), and did not vary significantly between age classes (Kruskal-Wallis test, adjusted for ties: $H_2 = 1.65$, $P = 0.438$). Our approach of using multiple feather samples per bird enabled us to estimate within-individual variation in our Bayesian multiple source isotopic mixing models ('Stable Isotope Analysis in R', SIAR; for details, see below), enhancing the robustness of model estimates for dietary proportions.

Additionally, we took blood samples from all subjects by piercing the vena ulnaris with a syringe needle and collecting drops of blood with sterile capillary tubes. Blood was immediately transferred into 90% ethanol and stored in Eppendorf tubes at room temperature until analysis (see below).

With regards to examining possible age-related variation in stable isotope profiles and diets, it is important to note that feathers sampled from juveniles had been grown at a different time of the year than those collected for older subjects. Thus, this temporal effect confounded potential age-related patterns. Furthermore, it is possible that, at the time of sampling, some birds that were scored by us as 'immature' according to their gape colouration still had their 'juvenile' feathers (i.e., they had not had their first moult yet), and that some 'adult' crows presented 'immature' feathers. While we have insufficient data on bird identities at this early stage of our field project to avoid such misclassifications, re-analysis suggested this was not a major problem. Even under an extreme scenario where all 'immature' crows (according to gape colouration) were re-classified as 'juveniles' (assuming that crows retain pink in their gapes for only the first year of life), there remained a significant age effect (raw δ^{15}N values, GLMM: $F_{1,20.0} = 2.77$, $P = 0.112$; percentage larva contribution to diet, GLMs on arcsine-square-root transformed data: protein, $F_{1,20} = 5.12$, $P = 0.035$; lipid, $F_{1,20} = 5.97$, $P = 0.024$), with 'juveniles' (mean ± SE; protein, 19.2 ± 1.8%; lipid, 48.2 ± 2.2%) having higher dietary intake values than 'adults' (which may contain some 'immature' birds, for reasons explained above) (12.0 ± 2.5%; 38.0 ± 3.8%) [compare with note (*21*) in the main text].

Our complementary set of blood samples overcame problems associated with the timing of feather growth. SIAR models produced, on average, very similar larva-contribution estimates for the two investigated tissue types (feathers and blood; see Fig. 2 and table S2), but since individual values were not strongly correlated (protein, $r_{22} = -0.268$, $P = 0.229$; lipid, $r_{22} = -0.235$, $P = 0.292$), we did not observe the same pattern of

age-dependent diet variation for blood samples as for feather samples (see main text). This is not an unexpected result, given: (i) that blood samples integrate dietary intake over a shorter time period (weeks prior to sampling) than multiple feather samples (usually several weeks to months prior to sampling, depending on when feathers were grown); and (ii) that blood and feather samples reflected dietary intake at different points in time. We suggest that future studies collect more data to corroborate our preliminary findings on possible age-related patterns. It will be particularly important to refine ageing techniques for NC crows (see above) and to collect more information on the timing of breeding and moult. Nevertheless, it is important to reiterate that the very high overall degree of consistency of our diet-composition and larva-intake calculations for the feather and blood datasets demonstrated that these analyses were robust for any possible temporal effects.

Food samples

We included the following seven food categories in our diet analyses (compare with Fig. 1): (i) longhorn beetle larvae (*Agrianome fairmairei*) [*n* = 29 samples; extracted from logs of six different candlenut trees (*Aleurites moluccana*), where crows were known to use tools for larva fishing]; (ii) candle nuts (*n* = 8; sampled from underneath live candlenut trees, and from local nut-dropping sites that were frequented by crows); (iii) carrion (*n* = 7 tissue samples from muscle and vital organs from 1 feral pig and 4 deer; sampled from carcasses and specimens shot by local hunters); (iv) 'invertebrates' (*n* = 4 groups, comprising 4 beetles, 4 amphipods, 2 centipedes and 1 wasp, and 2 spiders; collected with water-filled pit traps and by sweep-netting, with a few samples obtained opportunistically during general fieldwork activities; it proved surprisingly difficult to obtain invertebrate samples in our study area, although the SD for invertebrates was much smaller than the SDs for several of the other less taxonomically diverse groups, indicating that we had obtained a representative sample); (v) lizards (*n* = 7; predominantly collected as by-catch with water-filled pit traps); (vi) snails (*Achatina fulica*) (*n* = 2; snails are difficult to find, and we only managed to obtain two samples, one of which was dropped by a foraging crow); and (vii) fruit [*n* = 9, comprising 6 fruit samples of *Cordia dichotoma* (Boraginaceae) and 3 acajou fruit *Semecarpus* sp. (Anacardiaceae), collected opportunistically during fieldwork, preferentially from trees where crows had been observed foraging on fruit; crows also eat *Ficus* sp. (Moraceae) fruit in the study area (*S4*), but these were not included; but see below]. Of course, some foods may only be available sporadically (e.g., carrion) or vary in abundance seasonally (e.g., fruit), but we would not expect this to affect our overall conclusions (see below).

Our diet analyses could only consider the contribution of food sources that had been

sampled and specified in diet-mixing models. We sampled food items that NC crows were known to consume both in our dry forest study site and elsewhere in New Caledonia [(*S4*, *S5*), and references cited therein], or which they were suspected to consume on the basis of the known foraging habits of other tropical, omnivorous *Corvus* species. Over-specified diet-mixing models have poor predictive power, or fail to converge. Following model-economy considerations, we therefore had to: (i) pool samples into meaningful groups where possible [we pooled fruit and (non-snail) invertebrate samples, respectively; see above]; and (ii) omit some foods, which crows may take occasionally, but which are probably of relatively minor importance (e.g., adult longhorn beetles, which are nocturnal and therefore rarely available to foraging crows). Birds' eggs could not be sampled for ethical and logistical reasons.

Examination of our raw data in Figure 1B suggests that our 'best professional judgement' approach produced adequate sampling of our birds' general food base. In fact, in three further expeditions since the completion of fieldwork for the present study, no major additional food sources were discovered, so our original assessment still holds. However, as in any other study that employs diet-mixing models for assessing diets of generalist foragers, and given the difficulty of observing foraging wild NC crows (see main text), it is impossible to rule out that some food sources may have inadvertently been omitted, and/or that others may have erroneously been included in diet-mixing models. Our sensitivity analysis (see below for methods and table S2 for results) explicitly addresses the possibility that the proportion of beetle larvae in crow diet may have been over- or underestimated, and indicates consistent results for a large parameter space. Furthermore, even if our isotope-based estimates of larva-intake rates were further reduced due to the erroneous omission of a food source, we would expect the overall nutritional significance of tool use to remain qualitatively unchanged, given the exceptionally high lipid content of beetle larvae (Fig. 2A) and the comparatively even dietary protein contribution across all food sources (Fig. 2, B and C).

Since snails and fruit had comparatively low $\delta^{15}N$ signatures (see Fig. 1B), and our sample size for snails was small, we collected additional samples in 2009 to corroborate our key results (n = 2 snails; n = 8 fruit, comprising 4 fruit samples each of *Cordia dichotoma* and *Ficus* sp.). For $\delta^{15}N$, values for both snails and fruit from 2009 overlapped considerably with those from 2006–2007 (means ± SD; snails: 2006/07, 4.8 ± 3.3; 2009, 5.5 ± 0.3; fruit: 2006/07, 3.2 ± 1.7; 2009, 4.3 ± 1.4). For $\delta^{13}C$, there was again considerable overlap for fruit (2006/07, –27.0 ± 0.6; 2009, –27.7 ± 1.2), but no overlap for snail tissues (2006/07, –27.4 ± 0.5; 2009, –24.5 ± 0.2). There are many reasons why $\delta^{13}C$ might change temporally and these have been reviewed extensively in the literature (*S6*). Importantly for our study, larvae remained distinguishable on the $\delta^{15}N$ axis from all other prey types, including snails

and fruit (irrespective of which samples were included), confirming that our estimates of dietary proportions are robust. For consistency, we base all our analyses on data collected in 2006–2007 (see above; note that the SDs for snails had to be calculated from two samples).

Comparatively stable $\delta^{15}N$ values for snails and fruit across years (see above) also suggest that temporal variation on this axis was small. Perhaps more importantly, standard deviations for the isotopic ratios of the seven food sources (Fig. 1B) were explicitly incorporated in our Bayesian diet-mixing models (see below), thereby capturing some of the uncertainty associated with potential temporal isotopic drift in dietary components. Finally, quantitative radio-tracking (841 man-hours, with >2500 fixes for 30 subjects; 2005–2007), and a growing database of re-sightings for colour-ringed and/or wing-tagged subjects (a total of 73 subjects were marked during 2005–2010), indicate a high degree of site fidelity in NC crows (unpubl. data), so it is unlikely that large spatial movements of birds caused systematic bias.

Stable isotope analyses

Crow feathers were cleaned with distilled water to remove any surface contamination, and subsequently dried. Surgical scissors were used to cut small sections down the rachis to give as long a period of dietary integration as possible. A sample of 0.6 mg was weighed into a tin cup (Elemental Microanalysis Ltd.), which was crimped prior to mass spectrometry. Blood samples were dried at 55 °C for 28 hours before further processing.

Prey samples were dried whole at 50 °C for three days. Lipids contain little nitrogen, are isotopically light with respect to carbon, and tend to be highly variable among individuals, all of which can complicate data interpretation (*S7*). Therefore, following standard practice, we extracted lipids from all prey, using a Soxhlet apparatus and 2:1 chloroform–methanol solvent mix. Each prey sample was weighed both before and after lipid extraction to determine its lipid content. To ensure thorough mixing, samples were ground with a pestle and mortar before weighing 0.6 mg of preparation into a tin cup, which was then crimped. Fruit and nuts were expected to have low nitrogen content, so larger samples of 1.8 mg were used to ensure accurate measurement of $\delta^{15}N$.

Stable isotope analyses were carried out at the NERC Mass Spectrometry Facility, East Kilbride. Stable nitrogen and carbon isotope ratios were measured simultaneously, for feather and food samples, following combustion at 1020 °C. This was achieved by continuous-flow isotope ratio mass spectrometry (CF-IRMS), using a Costech (Model ECS4010) elemental analyser interfaced with a ThermoFisher Scientific Delta V Plus isotope ratio mass spectrometer.

Following conventions, stable isotope ratios are expressed as parts per thousand (‰ =

permil) delta-notation values ($\delta^{15}N$ and $\delta^{13}C$), which refer to international standards for carbon (PeeDee Belemnite) and nitrogen (air), using the following equation:

$$\delta X = [(R_{sample} / R_{reference}) - 1] \times 1000 \qquad \text{eqn (1)}$$

where X is ^{15}N or ^{13}C and R is the corresponding ratio $^{15}N/^{14}N$ or $^{13}C/^{12}C$.

Quantification of diet

To quantify the relative contribution of each food source to an individual crow's diet, we used the recently developed package 'Stable Isotope Analysis in R' (SIAR) v. 4.0 (*S8–S10*), implemented in the statistical programme R (v. 2.7.0). In our study, we had seven dietary sources (see above) with only two isotopic axes to resolve them upon. This means that our diet-mixing model is undetermined, and thus for each consumer value there are multiple feasible solutions for the relative contribution of each source to the diet. Until recently, the only models available for analysis of such datasets used single point estimates for the input parameters (source values; trophic enrichment factors; consumer values) and as such there was no way of assessing which of the myriad of solutions were most likely. SIAR is a Bayesian multiple source isotopic mixing model that incorporates uncertainty in sources (diets), trophic enrichment factors and consumer tissues. It also includes an error term to account for unquantified variation (e.g., physiological differences among individuals or un-measured food sources), and allows incorporation of elemental concentration. Thus, SIAR incorporates much of the variation that exists within dietary systems and, as a consequence, generates true probability density functions (PDFs) for the estimates of the relative contribution of each source to the consumer's diet. SIAR estimates are at their most robust when multiple isotopic measurements (of the same tissue type) are made for each individual as this allows estimation of the variation within individual consumers (in our case, with one exception, 4 or 5 feather samples per bird; see above). Finally, unlike some other diet-mixing models, SIAR incorporates concentration dependence (*S11*), because elemental concentration is rarely equal across all food sources, and ignoring this can bias model outputs.

Diet-feather trophic enrichment factors of 3.8 ± 1.0 ‰ for $\delta^{15}N$, and of 2.0 ± 1.0 ‰ for $\delta^{13}C$ were obtained from the literature, based on values for multiple bird species, including several estimates from passerines (*S12–S14*). This is likely to produce conservative estimates of the reliance of NC crows on tool use as studies on the smaller passerines tend to indicate larger enrichments than this (possibly linked to high protein diets), which would yield higher estimates of larvae in the diets of our study birds. Diet-blood fractionation

values of 2.25 ± 1.0 ‰ for $\delta^{15}N$, and of 0 ± 1.0 ‰ for $\delta^{13}C$ were taken from Hobson and Clark's study (*S12*) on American crows (*Corvus brachyrhynchos*). Some studies assume similar values for trophic enrichment across age classes [e.g., (*S15*)]. While our SIAR modelling approach allowed us to account for the fact that fractionation might vary between adult, immature and juvenile NC crows, it seems highly unlikely this was actually the case (e.g., we might expect increased $\delta^{15}N$ values in juveniles as a result of their more rapid metabolism, but the opposite was the case).

Importantly, correlations in our models between the predictions for larva contribution to crow diet and those for other sources were weak (≤0.25; correlations between sources only become a problem for the interpretation of SIAR outputs if they are greater than 0.5–0.6; A. Parnell, pers. comm.), and distributions of feasible solutions were narrow, indicating that the PDFs generated for this source were robust. Thus, we were able to use measures of central tendency from the PDFs to estimate the amount of larvae consumed by individual crows, and thereby their dependence on tool-derived food.

For the following reasons, routing was unlikely to be a problem for our analyses: (i) the macronutrient composition of larvae and nuts is similar [in fact, larvae have slightly higher lipid concentrations than nuts (38.63 ± 2.89% *vs.* 35.24 ± 2.25%); see Fig. 2A and table S1]; (ii) our Bayesian diet-mixing models deal with any potential concentration dependence (even though this is unlikely to be a problem in our case, because of the similarity in composition); and (iii) we examined two tissue types with quite different biochemical compositions (feathers and blood), and thus patterns of routing are likely to vary (despite this, the estimates of larva contribution to diet are very similar for both tissues; see Fig. 2, B and C and table S2). Finally, by including concentration dependence in our diet-mixing models we also deal with the risk of overestimating larva contributions due to the underestimation of sugar-rich but protein-poor fruit.

Dietary lipid contribution, larva-intake rates and energy budgets

Given that dietary components varied substantially in their lipid contents, we used SIAR estimates of protein contribution, and the lipid content of prey, to estimate the contribution of each dietary source to the lipid intake of individual crows. This was done by taking the proportion of lipid in each prey type, multiplying it by the estimated proportion of that prey item in the diet, and then expressing this figure as a proportion of the total contribution of lipid from all sources.

To evaluate the potential nutritional significance of larvae, and therefore tool use, to NC crows, we estimated: (i) the average number of larvae an individual bird consumes per day (for results, see table S2); and (ii) the average number of larvae that an individual

would need to consume to meet its daily energy requirements (for results, see main text). We based our calculations on the following equation [adapted from (*S16*)]:

$$b = d \times p / e \times a \qquad \text{eqn (2)}$$

where: *b* is the biomass of larvae consumed per day in grams (to calculate the number of larvae consumed, we divided *b* by the average dry mass of a single larva which is 1.4 g, with a minimum of 0.44 g and a maximum of 2.28 g used in the sensitivity analyses); *d* is the daily energetic requirement of an individual in KJ/day [*d* was calculated from allometric scaling relationships for passerine birds (*S17*), using individual NC crow body masses, as measured at the time of capture]; *p* is the proportion of larvae in the diet (based on SIAR estimates; see above); *e* is the energetic value of the prey in KJ/g, using a lipid energy content value of 9 kcal (37.7 KJ) per gram (*S18*) (*e* varies with the size of larvae due to differences in the proportion of lipid, such that the value for an average-sized larva is 150 KJ/g, with a minimum of 100 KJ/g and a maximum of 299 KJ/g used in the sensitivity analyses); and *a* is the assimilation efficiency for the food source (0.75) (*S19*).

To assess the robustness of our estimates, we conducted sensitivity analyses of the key components in the model, using individual parameter perturbation (table S2). Input parameter values were changed at the level of the individual bird, where appropriate, using confidence intervals of the original estimates (for details, see caption of table S2). Despite exploring a large parameter space, estimates of larva-consumption rates remained within the same order of magnitude.

Unfortunately, we currently do not have any data that would be suitable for robust cross-validation of our isotope-based estimates. While our video-surveillance results appear to indicate lower intake rates, we note that there was very large temporal (and spatial) variation in larva-extraction rates [see fig. S4 in (*S1*)]. This variation would need to be taken into account in any attempt to extrapolate data from our few video-monitored candlenut logs to other larva-fishing sites in the study area, and would in fact result in extraction estimates similar to our lower isotope-based values (compare with table S2). Using our video dataset for individual-level validation is impossible (e.g., crows did not forage exclusively at video-monitored sites), but it is reassuring that both techniques (video surveillance and stable isotope profiling) independently identified the same crow as the most prolific adult tool user (see main text). Preliminary analyses of our radio-tracking data show that all sampled, resident crows had potentially access to active larva-fishing sites. Some crows had home ranges encompassing only few (known) sites, which would suggest smaller larva-intake rates than indicated by our isotope results, but these birds lived in a valley where larva-fishing opportunities had not been surveyed systematically, so it is

impossible to draw firm conclusions.

Statistical analyses

Variation in raw $\delta^{15}N$ feather values was analysed with generalised linear mixed models (GLMMs; normal error structure and identity link function; REML algorithm), with 'bird identity' fitted as a random effect to account for the non-independence of multiple feather samples that had been collected from individual crows. Significance of predictors was assessed using approximate *F*-statistics with estimated error degrees of freedom. All other analyses used simple general linear models (GLMs), with Tukey post hoc comparisons where appropriate. Proportional data were arcsine-square-root transformed prior to analysis. Models were implemented in GenStat v. 12 (GLMMs) and Minitab v. 14 (GLMs), and model fit was checked in both packages by inspecting diagnostic scatter plots of standardised residuals.

Authors' contributions

CR conceived the original project idea; CR and SB designed the study, with input from LAB; CR and LAB organised and led the field project, and together with JT, they collected crow and food samples and all complementary field data; NR and RI prepared samples for stable isotope analyses; NR carried out lipid extractions; NR and JN analysed isotope samples; NR, SB and RI analysed and interpreted isotope data; NR and SB produced the energy-budget model, with input from AK and CR; CR, NR, SB and RI conducted statistical analyses; CR and JT prepared figures; LAB and JT prepared the movie; JT took the photos shown in figures S1 and S2; AK and CR obtained funding for fieldwork; CR, LAB, NR, JT, JN, RI, AK and SB discussed and interpreted results; CR drafted the manuscript; NR, CR and SB drafted the methods section; CR, LAB, NR, JT, JN, RI, AK and SB read, and commented on, several manuscript versions; and CR, LAB, NR, RI, AK and SB edited the manuscript.

Figure S1. A wild New Caledonian crow uses a stick tool (**top**) to fish for a wood-boring beetle larva (**bottom**) at a degrading candlenut log. Note how the tool remains inserted into the burrow after the larva has been extracted (bottom) (20 January 2009; Vallée Taro).

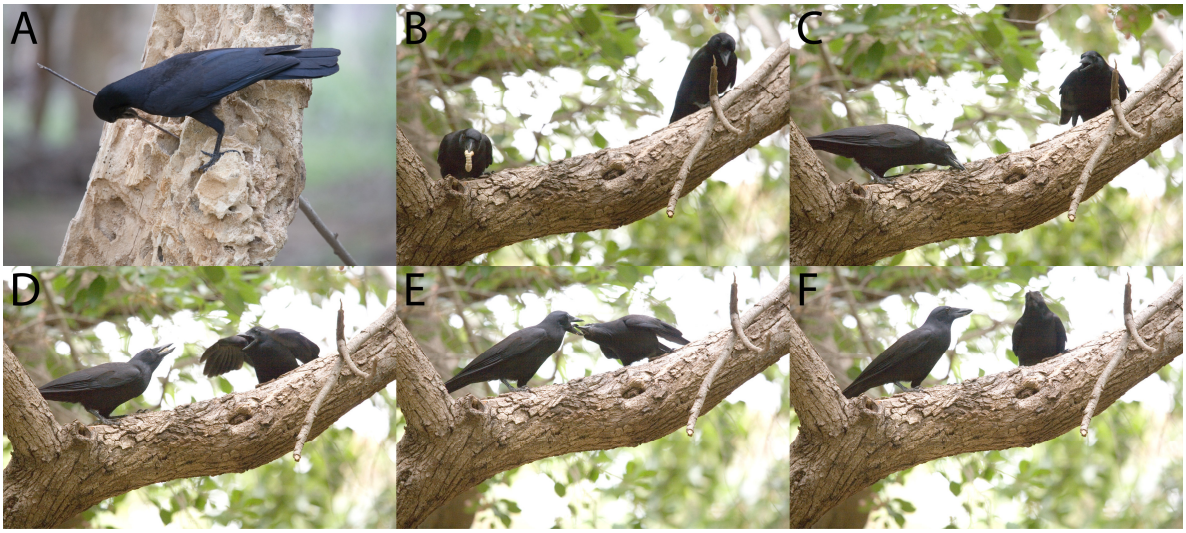

Figure S2. An adult New Caledonian crow feeding a nutritionally independent immature crow with a wood-boring beetle larva (10 January 2009; Vallée Taro). (**A**) 8:28:46 — Crow *A* is using a long tool to extract a larva from an artificially positioned log (*Aleurites moluccana*) that was provisioned with live larvae. 8:29:39 — Crow *A* picks up the larva, flies into a nearby tree (*ca.* 3–4 m away from the log) and perches on a branch where crow *B* is begging (body posture and vocalisations). (**B**, **C** and **D**) 8:29:49 — Crow *A* positions the larva head-first in its beak, perched *ca.* 30 cm away from crow *B*. (**E** and **F**) 8:29:50 — Crow *B* moves towards crow *A* and accepts the regurgitated larva. Crow *A*, probably a young breeding male, was positively identified from unique leg-scale and scarring patterns and was known to be a competent tool-user based on observations of proficient extraction of heart-pieces during an earlier experiment at the same site. Previous observations of crow *A* indicated a very small amount of pink colouration in its gape, but the tongue was all black. Crow *B* could not be identified from leg scales or scars when this observation was made, but it had identical moult condition to a known individual (where moult condition had previously proven to be a reliable means of identification). Furthermore its interactions with crow *A* resembled those typically shown by this individual (soft vocalisations, subordinate behaviour). According to moult condition and the grey-pink colouration of the gape, crow *B* was an immature bird of >1 year old. Across 34 days of observations, crow *B* was observed begging 20 times, at least 5 times in the presence of crow *A*. On these occasions, crow *A* appeared dominant over crow *B*, and occasionally displaced it from the baited log.

Table S1. Nutritional composition of the seven principal food sources of wild New Caledonian crows: %N (a proxy for protein content), %C (a proxy for CHO content), and C/N ratios (mean ± SD) (compare with Figs 1 and 2). For further details on the use of these proxy measures, see (*S20*).

food source	%N	%C	C/N
larvae	7.65 ± 2.41	60.62 ± 1.81	8.82 ± 3.13
nuts	7.58 ± 0.92	66.87 ± 4.68	9.02 ± 1.90
carrion	12.36 ± 1.27	61.80 ± 1.62	5.04 ± 0.50
invertebrates	9.73 ± 2.89	53.85 ± 8.86	5.77 ± 1.10
lizards	10.50 ± 1.18	48.71 ± 5.97	4.64 ± 0.13
snails	9.00 ± 5.26	54.81 ± 7.31	7.06 ± 3.31
fruit	1.70 ± 0.72	56.03 ± 2.97	39.07 ± 18.24

Table S2. Nutritional significance of wood-boring beetle larvae for wild New Caledonian crows. The table illustrates the effect of varying parameter values upon estimated larva intake by crows (number of larvae consumed per day). The original estimate, using mean values for all parameters, is 1.80 ± 0.37 larvae (feather data, mean ± SD; blood: 1.83 ± 0.41 larvae). Lower and upper values for *d* were calculated using the 95% confidence intervals for the allometric scaling equations given in (*S17*). Lower and upper values for *p* were the 50% confidence intervals given by SIAR. Lower and upper values for *e* were calculated based on the different sizes and lipid contents of larvae; thus, to calculate the number of larvae consumed, we used for the upper estimate (estimate 1) a value of 100 KJ/g and a dry mass of 0.44 g per larva, and for the lower estimate (estimate 2) a value of 299 KJ/g and a dry mass of 2.28 g per larva.

parameter		**input values**		**larvae consumed per day**	
		lower (1)	upper (2)	estimate 1	estimate 2
daily energy requirements (*d*)	feathers	383.75 ± 32.17 KJ/day	1020.57 ± 107.63 KJ/day	1.10 ± 0.22	2.93 ± 0.60
	blood			1.12 ± 0.24	2.98 ± 0.69
beetle larvae in diet, in relation to lipid content (*p*)	feathers	36.65 ± 9.60%	56.30 ± 9.60%	1.45 ± 0.38	2.23 ± 0.41
	blood	37.33 ± 8.65%	54.63 ± 8.65%	1.48 ± 0.40	2.17 ± 0.43
larva energy content (*e*)	feathers	100.00 KJ/g	298.98 KJ/g	8.59 ± 1.74	0.55 ± 0.11
	blood			8.72 ± 1.95	0.56 ± 0.13

Movie S1. This movie illustrates how wild New Caledonian (NC) crows use stick tools to fish for wood-boring beetle larvae. (**Scene 1**) (26 November 2006; Vallée Tabou) was filmed with a motion-triggered, autonomous video camera [see (*S1*)] and shows a male crow foraging at a naturally degrading candlenut log. The scene shows the final 20 seconds of a 141 second-long foraging bout during which the bird repeatedly probed the burrow with a tool (total time spent holding tool, 72 seconds), prior to extracting the larva. Note the large number of exposed larva burrows in the log, which give it a 'honeycomb' appearance. (**Scene 2**) (6 January 2009; Vallée Taro) was filmed with an infrared video camera hidden inside an experimental log, with a live larva offered in a plastic tube surrounded by mirrors (footage is rotated 90 degrees clockwise, i.e. the tube was oriented vertically in the experiment). The stick tool, coming into view from the right, is inserted by a wild, unmarked NC crow. Note how the crow makes repetitive, 'teasing' movements with the tool, and how the larva opens its mandibles in defence, before latching onto the tip of the tool and being levered out of the artificial burrow.

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