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Rapid development of cleaning behaviour by Torresian crows Corvus orru *on non-native banteng* Bos javanicus *in northern Australia*

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In this paper we report the observation of a rapidly developed vertebrate symbiosis involving ectoparasite cleaning by a native corvid of northern Australia, the Torresian crow *Corvus orru*, on a recently introduced bovid ungulate, the banteng *Bos javanicus*. Facultative symbioses benefiting both participants (mutualisms) between birds and mammals appear to be rare, despite the apparent advantages obtained by the participants (ecto-parasite removal from the host and food provision to the cleaner). On three separate dates we observed a total of four *C. orru* individuals eliciting facilitation behaviours by a total of ten female banteng to assist in the removal of ectoparasites. Our observations document the first-known incidence of facultative cleaning behaviour by a native bird species on a non-native, wild vertebrate that has developed in approximately 150 years since the banteng's introduction to Australia.

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The evolution of inter-specific symbioses has received much attention with respect to its effects on individual behaviour, life-history strategies, population dynamics and patterns in biodiversity (review by Sachs et al. 2004). Any interrelationship between two species living together can be defined as a symbiosis (Boucher et al. 1982), and symbioses can take the form of mutualism (mutually beneficial for both participants - Grutter 1999), commensalism (only one participant benefits while the other receives none - Boucher et al. 1982), or parasitism (one participant benefits at a cost to the other - Weeks 1999). In general, it is thought that mutualisms allow better survival in marginal habitats especially when nutritional benefits are involved, and mutualisms tend to be more stable than other forms of symbiosis (Boucher et al. 1982). Although some mutualisms appear to be highly evolved, mutualisms can apparently form without evolution (Janzen 1980, Boucher et al. 1982).

Facultative mutualisms between birds and mammals are rare despite the apparent advantages obtained by the 'host' mammal (usually, ecto-parasite removal) and the bird (usually, food ingestion). African jacanas *Actiphilornis africana* and finfeet *Podica senegalensis* perch on the backs of forest buffalo *Syncerus caffer nanus*, bongo antelope *Tragelaphus euryceros* and hippopotamus *Hippopotamus amphibius* to pick off invertebrates on or near their host (Pooley 1967, Ruggiero 1996, Ruggiero and Eves 1998), and Hartlaub's ducks *Pteronetta hartlaubii* glean invertebrate prey from swimming forest buffalo (Ruggiero and Eves 1998). Facultative mutualisms of this type involve pairs of species that have co-evolved in the same environment. However, with changes in potential host range due to introductions of non-native species, novel symbioses may arise (Weeks 1999). This provides an opportunity to determine the rate at which new symbiotic relationships develop between vertebrates because the history of many introductions is known.

In this paper we report the observation of a rapidly developed vertebrate symbiosis between previously unacquainted species that appears to be mutualistic. The behaviour involves ectoparasite cleaning by a native corvid of northern Australia, the Torresian crow *Corvus orru*, on a recently introduced bovid ungulate, the banteng *Bos javanicus*. Banteng were introduced to one small (2,200 km^2) peninsula (Cobourg) in northern Australia in 1849 (Calaby 1975), and now the population is estimated at 5,000 to 7,000 individuals (K. Saalfeld, unpubl. data). The Torresian (or Australian) crow is the only corvid species found in tropical northern Australia, but it occurs as far south as Brisbane on the eastern coast and its range has increased in response to human modifications to the landscape (Sewell and Catterall

1998). A large proportion of its diet consists of invertebrates, although they are opportunistic omnivores that also consume plant material and carrion (Rowley and Vestjens 1973). The mainland Australian race *C. orru ceciliae* occurs exclusively in Australia, but other *C. orru* races (*C. o. orru, C. o. insularis, C. o. latirostris*) occur on Southeast Asian islands to the north (Sinclair 1998). There are no reports of corvids in Australia involved in mutualistic interactions with either native or introduced vertebrates. Although there are many endemic corvid species occupying the native range of banteng in Indonesia (Sinclair 1998), Torresian crows do not occur in the actual or historic range of banteng in their native range.

Materials and methods

Free-ranging banteng from Garig Gunak Barlu National Park, Cobourg Peninsula, Northern Territory, Australia (11°20′S, 132°20′E) were tracked from 5–11 September 2004 as part of a larger study sampling skin tissue for genetic analyses to determine the degree of hybridization (Bradshaw et al. 2005, 2006). Opportunistic observations of mutualistic behaviours were made from a distance of 15–45 m from resting or feeding wild banteng. All sampling procedures were approved by the Charles Darwin University Animal Ethics Committee, and authorized under a Parks and Wildlife Service of the Northern Territory Permit to Take Wildlife for Commercial Purposes (No. 18275).

Results

While tracking banteng we observed behavioural interactions between individual banteng and Torresian crows on three separate dates (5, 10 and 11 Sept. 2004) involving a total of ten adult female banteng and four crows. The three occasions all occurred in patches separated by 20–75 km.

Each interaction proceeded as follows: (1) we observed a crow landing on the back of an adult female banteng while she was lying on her belly, (2) after the crow had landed, it walked along the back of the banteng until the banteng rolled onto her side and lowered her head to the ground, (3) this behaviour was followed by the banteng lifting her upper legs as high as possible to allow the crow to gain access to the areas under the legs and belly. The banteng demonstrated obvious signs of discomfort and exertion during this behaviour (bulging eyes; veins prominent in the shoulder, neck and face), (4) at this point the crow moved to the ground near the prostrate banteng and picked at ectoparasites (presumably Ixodid ticks) from the exposed areas, mainly between the banteng's elevated rear legs. Each grooming bout lasted approximately 10 s, at which point the banteng raised her head and returned to lying on her belly (possibly from the fatigue caused by maintaining the legs elevated), (5) this action was followed by the stoppage of grooming by the crow, and its flight to a nearby tree branch, and (6) another bout usually followed within 10 to 15 s with the crow re-alighting on the banteng's back (or on the ground nearby in the last observation) and eliciting the entire process once again.

On the first occasion (5 Sept. 2004), a mixed herd of 12 individual banteng were bedded when a single crow landed on the back of a female banteng while she was lying on her belly. The interaction described above occurred only once prior to the herd moving off after detecting the observer. On the second occasion (10 Sept. 2004), a single crow was observed interacting with one female banteng in a herd of four bedded animals in the manner described. A fifth female banteng joined the group after 10 min into the observation period and after lying down, the crow moved to this new female and began the cleaning behaviour. The crow repeated the cleaning behaviour with three other female banteng in the herd over the next 30 min (single grooming of each animal with the exception of one banteng that was groomed 3 times) when we ceased the observation. On the third occasion (11 Sept. 2004), four female banteng were bedded when a crow began the cleaning behaviour with one of them. A second crow then began grooming another banteng simultaneously. After ceasing each interaction, the latter crow flew to a nearby tree branch for a few minutes and then re-alighted on the same banteng (repeating this sequence two more times). Both crows cleaned a total of two banteng each over the next 30 min.

Discussion

Our observations document the first-known incidence of facultative cleaning behaviour by a native bird species on a non-native, wild vertebrate. Although the number of observations was low, the symbiosis appears to benefit both participants – i.e. it is a mutualism. More importantly, this apparent mutualism appears to have developed since the introduction of banteng to the Cobourg Peninsula approximately 150 years ago. Furthermore, the mutualism appears to be widespread within this population because it was seen in three widely separated locations over a short period of investigation.

Although the observed behaviour appears to be mutualistic, apparently reciprocally beneficial symbioses of this type can turn out to be disadvantageous to the recipient of the cleaning behaviour. For example, there is evidence that oxpeckers do not necessarily reduce tick-loads in African ungulates (Weeks 2000) and prefer to

feed on blood from pre-existing wounds or those created by 'scissoring' with the bill (Weeks 1999, McElligott et al. 2004). Whether Torresian crows exploit banteng in ways not observed here remains to be shown. Indeed, Torresian crows have learnt to exploit at least one other introduced species: they flip poisonous cane toads *Bufo marinus* onto their backs and feed on the non-toxic innards and flesh of the legs (Donato and Potts 2004).

Despite the uniqueness of the observed cleaning behaviour, corvids world-wide are known for their ability to learn and discern landscape features (Kamil and Jones 1997, Templeton et al. 1999, Jones et al. 2002), and associate with other species for food resources (e.g. scavenging; Stahler et al. 2002). Although cleaning mutualisms have yet to be described for other corvid species, it is possible that similar mutualisms exist in the native range of banteng in areas where native populations remain; however, there are no reports to confirm this. The rapid development of this behaviour by the Torresian crow in our study is analogous to the exploitation of domestic cattle *Bos taurus* as hosts for native oxpeckers in southern Africa (Weeks 1999) and illustrates the plasticity of their behaviour. What is unique in the crow-banteng symbiosis is the facilitation behaviour of rolling onto the side and leg-lifting demonstrated by banteng. This has not been reported for the oxpecker – *B. taurus* symbiosis in Africa. Facilitation behaviour has previously only been observed in native species that have co-evolved over much longer periods. For example, African forest buffalo facilitate jacanas in search of invertebrate meals by rolling onto their side to allow access to lower parts of the body or by ceasing to flap their ears and tail (Ruggiero and Eves 1998).

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