

Use of dung as a tool by burrowing owls

This bird distributes animal dung in and around its burrow to provide a bait for its prey.

Reports of tool usage by birds tend to be anecdotal as only a few individuals may be involved¹ and the behaviour observed can often be interpreted in other ways^{2,3}. Here we describe the widespread collection of mammalian dung by burrowing owls (*Athene cunicularia*) and show that they use this dung as a bait to attract dung beetles, a major item of prey. Our controlled investigation provides an unambiguous estimate of the importance of tool use in a wild animal⁴.

Burrowing owls place mammalian dung in and around their burrows⁵ (Fig. 1). If removed, it may be rapidly replaced, suggesting that it is more than an incidental accumulation of debris⁶. Because burrowing owls are one of the main predators of dung beetles^{5,7} and stand motionless for long periods by their burrows, we investigated whether they could be using mammalian dung as bait to 'fish' for dung beetles. The largest common species of dung beetle at our study site (*Phanaeus igneus*, 2 cm in length) is diurnal, as are the owls. This species makes up 65% of the beetles consumed by the owls ($n = 20$ owl pellets analysed). Alternatively, mammalian dung may mask the scent of the nest from predators⁶, given that the nests of burrowing owl are accessible to a wide range of terrestrial predators and that many nests are lost to them⁵.

To test this idea of olfactory camouflage, we created 50 nest burrows, spaced 50 m apart, and placed five quail eggs in each; every alternate burrow received cow dung. We recorded nest fate every two days for



Figure 1 Baiting and waiting: an owl stands at the entrance to its burrow, surrounded by the dung that it has positioned to entice beetles.

3.5 weeks, which is a typical incubation period. All but one nest was discovered and destroyed by predators. Survival analysis revealed no difference in time to destruction between nests with and without dung (Cox log-hazard ratio of 0.62 ± 0.31 , $z = 1.58$, $P > 0.10$). We conclude that dung does not effectively mask the scent of eggs. It may, however, be effective at masking the scent of chicks, which we did not test for ethical reasons.

To test the baiting hypothesis, we first removed all dung, regurgitated pellets and beetle parts from the burrow entrances of two owl populations. Half received 231 ± 16 g (dry mass) of cow dung, typical of the amount found at a burrow entrance; the remainder received no dung but were otherwise treated in the same way. After four days, we collected all prey remains and regurgitated pellets from the burrows and repeated the experiment, this time switching the treatment and control burrows. We found that when dung was present at the burrows, owls consumed ten times more dung beetles and six times more dung-beetle species than when dung was not present ($P < 0.001$; Fig. 2).

A few instances of tool use by wild birds are wonderfully detailed and widely accepted^{1,4}. More generally, however, the ecological and evolutionary significance of tool use is difficult to judge because evidence for how such behaviour benefits wild animals is scant⁴. Trials with captive animals have shown that they have surprising abilities⁸, but such results are difficult to extrapolate to natural settings. Baiting with dung and then waiting for dung beetles to come is akin to the use by herons of floating objects (such as bread, feathers and insects) as tools to attract fish⁹, although the foraging success with and without 'bait' has not been compared. Our experiment provides such a comparison, demonstrating that tool

use can substantially benefit a wild animal.

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Botany

A new self-pollination mechanism

Pollen grains from most flowering plants are transported by wind or animals and deposited on the receptive surface of the stigma of a different individual, but self-pollination is also common. We have discovered a new process for self-pollination in the laterally orientated flowers of a Chinese herb, in which a film of pollen is transported from the anther (pollen sacs) by an oily emulsion that slides sideways along the flower's style and into the individual's own stigma. This mode of

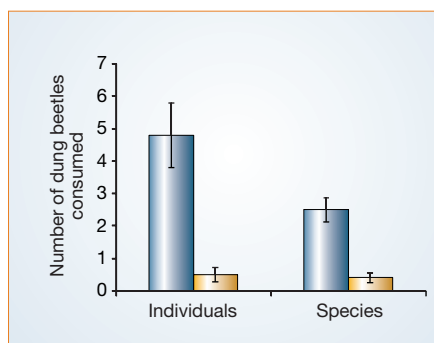


Figure 2 Number of dung beetles consumed by burrowing owls in the presence (blue) and absence (orange) of cow dung positioned at their burrows. Averages and standard errors are shown; $n = 10$ burrows per treatment in two populations (Gilchrist County, Florida). $P < 0.001$ for both the number of individuals and the number of species (in paired t -tests). Beetles were identified by their elytra, which owls commonly discard before consumption or regurgitate in pellets. Because we restricted our sampling of prey remains to the immediate vicinity of each burrow (to an area of about 0.75 m^2), the total number of beetles consumed during the trials will have been higher than indicated.

self-pollination is a new addition to the broad range of genetic and morphological mechanisms that have evolved in flowering plants (angiosperms)¹, and may be common in species growing in shady, windless and insect-poor habitats.

Caulokaempferia coenobialis (Hance) K. Larsen is a deciduous perennial herb of up to 50 cm in height. It is endemic in the Guangdong and Guangxi provinces of southern China, where it hangs on rock walls in humid monsoon forests^{2–4}. Plants flower from May to August and generally produce three buds that open consecutively. Flowers open between 6:00 and 6:30 in the morning, last for two days, and fade during the afternoon of the second day. Capsules mature and burst open, or dehisce, within 22 days. Seeds germinate and develop into seedlings that develop rhizomes before the plants die back between September and November, depending on the onset of the dry season. New plants develop from these rhizomes after the start of the next rainy season.

We studied the pollination biology of *C. coenobialis* in several large populations (2,000–10,000 flowering individuals) growing in the Dinghushan and Nankunshan nature reserves in Guangdong province in 2002, 2003 and 2004. *C. coenobialis* flowers have yellow corollas, with two short lateral lobes and one large central lobe of up to 3 cm long (Fig. 1a).

Although the precise phylogenetic affinities of *Caulokaempferia* within Zingiberaceae remain unresolved^{3,5}, the species has a flower structure typical of this family, with two elongated, lengthwise-dehiscing pollen sacs that enclose the style. The concave stigma lies almost exactly at the end of the pollen sacs (Fig. 1b). It resembles the stigmas of other Zingiberaceae, which are characterized by wet (secretory), papillose surfaces⁶. As in some other Zingiberales^{7,8}, the pollen grains in *C. coenobialis* are held together by pollen-connecting threads and have an abundance of oily pollenkit on their surface (as confirmed by staining with Sudan III and IV). Pollenkit is a mixture of hydrophobic components produced by the inner lining of the anther (tapetum). It consists of lipids and a species-specific admixture of carotenoids, proteins and carboxylated polysaccharides⁹. It is also abundant in other angiosperms, especially bee-pollinated varieties⁹.

The pollenkit in *C. coenobialis* is clear and rich in unsaturated lipids. It forms an oily film in which the pollen grains are suspended (Fig. 1c,d). Soon after anther dehiscence in the morning, a drop of pollen spills from each pollen sac. The two drops merge to form a film that quickly spreads across the style surface and slides towards the stigma (Fig. 1c,d). A fringe of hairs around the style may prevent the pollen from spilling off the style.

Spreading of the pollen film occurs

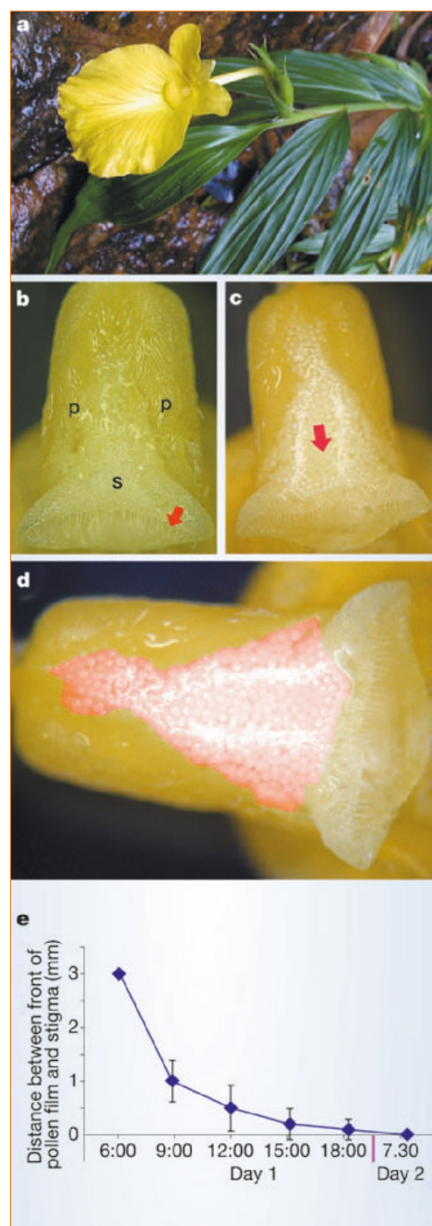


Figure 1 Pollen sliding in *Caulokaempferia coenobialis*. **a**, The flower in its natural position. **b**, The stigma (s) and the anther, consisting of two pollen sacs (p), which have pollen streams coming from them; arrow indicates stigma hairs. The stigma is about 3 mm in diameter. **c**, Pollen film sliding (arrowhead) towards the stigma. **d**, Pollen film stained red with Sudan III (computer reproduction of an actual experiment): the pollen film is on the style surface, about 0.2 mm from the stigma's margin; the pollen grains are visible in the oily film. **e**, Distance travelled over a period of about 25 hours by the pollen film as it flows from the pollen sac towards the stigma (distances are measured between the pollen-film front and the stigma; mean values \pm s.d.; $n=20$).

rapidly (Fig. 1e), the rate being comparable for plants in the laboratory, at 25–65% relative humidity, and plants in their nearly saturated natural habitat on outcrops in forests. The film arrives at the stigma margin, where there is a row of fine hairs, and passes between them at about 15:00, at which point self-pollination begins and continues until the next morning.

The rate of fruit set in five populations fol-

lowing controlled hand self-pollination ($95.93 \pm 4.77\%$, $n=49$) and cross-pollination ($97.96 \pm 4.97\%$, $n=49$), in which a drop of pollen was placed directly on the stigma, does not differ significantly ($t=0.6622$, $P>0.05$), indicating that *C. coenobialis* is capable of selfing without detrimental effects on seed set. There was also no significant difference ($t=0.1717$, $P>0.05$) between the rate of fruit set in control flowers and in flowers bagged before opening ($75.93 \pm 22.37\%$, $n=50$, compared with $77.89 \pm 12.63\%$, $n=95$). The species is incapable of asexual seed set, as shown by the absence of seed set in flowers that had had their stamens or stigmas cut off before they could self-pollinate ($n=50$ for each experiment).

To our knowledge, this is the first report of pollination in angiosperms by pollen that is conveyed in a mobile secreted medium. The lateral flow of the film of pollen along the style seems to be due only to the spreading properties of the oily emulsion and not to gravity. Analysis of the style and stigma under a scanning electron microscope reveals a smooth style and stigma surface, and no channels or grooves. During more than 20 days of observation (about 200 hours), we never witnessed any insects visiting the flowers that would have touched the anthers and stigmas, even though each flower can offer up to two microlitres of nectar containing 18% sugar. Selfing by virtue of pollen sliding to the stigma may have evolved as a strategy to cope with a scarcity of pollinators in the extremely shady and humid habitats of *C. coenobialis*.

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Superconductors: Time-reversal symmetry breaking?

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