The highlight for June is provided by Dr. Sandra Baker of the Wildlife Conservation Research Unit in the Department of Zoology at the University of Oxford. In the tradition of Carl Gustavson and Lowell Nicolaus, Dr. Baker has sought ways to use CTA learning to curtail the consumption of domestic resources by wildlife. While her interest in the use of CTA for wildlife control is broad, her most recent work focused on developing a method of preventing European badgers (Meles meles) from foraging on domestic crops. Key to the sustained protection of food resources is the need to condition and maintain aversions that minimize sampling of the averted food. Using biscuit bait treated with a formulation of ziram, a fungicide known to produce feeding aversions in other animals, Dr. Baker and colleagues demonstrated that badgers would eventually avoid ziram-contaminated bait after repeated sampling. Noting that bait rejection often occurred at a distance, they hypothesized that an odor cue was contributing to the bait rejections. However the odor cue was likely a property of the particular formulation of the ziram treatment and not the bait itself. Dr. Baker and colleagues modified the treatment, using a pure form of ziram and incorporating a novel effusive odor, clove oil, to provide an effective odor cue for 'unpalatable' bait. Badgers that ate bait treated with the ziram-clove oil formulation subsequently avoided untreated bait in the presence of the clove oil scent. These findings showed it was possible to condition food aversions in badgers in a way that deterred sampling of untreated target foods. Dr. Baker and colleagues have subsequently extended these findings to an actual domestic product, maize cobs. This nice series of experiments by Dr. Baker and colleagues highlights the usefulness of CTA learning in the humane management of our agricultural interests and is a good example of the versatility of CTA as a behavioral tool.

Badgers, CTA and second order conditioning

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Wild mammals cause foraging damage to crops worldwide. However, lethal methods of managing wildlife can be inappropriate for efficacy, ethical, conservation and legal reasons, and alternatives need to be developed. I highlight here a series of iterative lab-style experiments that aimed to identify a practical non-lethal method of controlling wild mammal foraging, using European badgers *Meles meles* as models - the first known CTA research on this species. Badgers make excellent models for this work because they are opportunistic omnivores, widely reported as crop pests and distributed across much of the northern hemisphere. This research, conducted at Oxford University's Wildlife Conservation Research Unit in collaboration with the Central Science Laboratory (both in the UK), began as a project funded by the UK Government's Ministry for Agriculture, Fisheries and Food (MAFF), as it then was. Subsequent work was funded by MAFF's successor, the Department for the Environment, Food and Rural Affairs, and by the Royal Society for the Prevention of Cruelty to Animals. From the relatively broad initial remit, the project ended up focussing on second order conditioning of odour cues for the protection of untreated foods. Crucially, by recording

CCTV footage of marked wild animals at field experiments I was able to examine detailed individual behaviour, which allowed me to identify the underlying mechanisms taking place.

Context

CTA is a type of learned food aversion with potential use as a wildlife management tool. Where learned food aversions are created in a resident population of a territorial 'problem' species, food preferences may be altered while other ecological relationships remain intact, e.g. continued exclusion of untrained conspecifics through territorial defence (Reynolds, 1999) – in other words the 'poacher' becomes the 'gamekeeper'. Many wildlife management situations demand the protection of untreated foods because it is neither desirable nor practical to treat the foods concerned (for example, those intended for human consumption, or live prey items, such as eggs (Conover, 1989)). However strictly taste-based aversion could not be expected to protect untreated foods from damage; by default, the target animal would need to experience the aversive taste every time before being averted (see Cowan *et al.* 2000). Aversion could not occur until the animal bit or licked (and probably damaged) the referent food (Nicolaus & Nellis, 1987). Therefore, successful applications of CTA in wildlife management have been limited mainly to reducing bird damage to seeds, ripening fruit, and lawns (Conover, 1989). In such cases, vulnerable items are sprayed directly with an illness-inducing chemical, and protection does not need to extend to untreated items.

Early attempts to use CTA for protecting untreated wildlife food items focussed on the defence of live prey. In 1974, Carl Gustavson and colleagues conditioned captive coyotes not to attack live sheep while retaining their appetite for alternative prey. Researchers quickly moved to ambitious, large-scale field trials that attempted to use CTA to deter wild coyotes from attacking sheep, but some trials were poorly designed and results were inconclusive. In the early 1980s, Lowell Nicolaus and colleagues established two important principles. First, Nicolaus *et al.* (1982) showed unequivocally (using raccoons and chickens) that it was possible to inhibit the killing of live prey under field conditions. Second, Nicolaus *et al*. (1983) demonstrated that conditioned aversion using model baits can cause extensive reductions in predation on mimics. For example, wild American crows (*Corvus brachyrynchos*) that ate green-painted eggs containing an emetic subsequently avoided green eggs whether or not they were treated.

Together with Ruth Cox and other colleagues, I used CTA to train captive carrion crows (*Corvus corone*) to delay their attack on a previously favoured egg colour even when this was subsequently untreated (Cox *et al*., 2004). We also established that crows did not generalize their aversion to eggs of a different colour, a potentially important consideration when designing realistic wildlife management strategies. Nicolaus and co-authors have now demonstrated the capacity of a variety of free-ranging egg predators to learn to avoid consuming eggs through CTA. These include ravens, crows, raccoons, mongooses, and guilds of mammalian predators. Ultimately our work with wild badgers – described below - extended this research by demonstrating that badgers could be conditioned, via CTA, to avoid foods on the basis of an odour cue alone. (This section was largely extracted from Baker *et al.,* [2007a]).

CTA and second order conditioning

We began our work to develop a non-lethal method of controlling badger foraging using a cafeteria-style experiment to determine whether any of three chemical food-based 'repellents' had the potential for manipulating badger feeding behaviour (Baker *et al*., 2005a). The repellents under test were ziram, capsaicin and cinnamamide, all known to have primary and secondary aversive properties. Repellents were applied to biscuit bait. During the treatment phase, treatment nights were alternated with control nights (untreated baits), to check for seasonal effects, and in the second part of the treatment phase we rotated the positions of baits, to check for positional biases. All baits were consumed on treatment nights 1 and 2. Ziram consumption then declined to zero between treatment nights 3 and 9, this coinciding with a sharp rise in bait patch rejection (see Figure 4 in Baker *et al*., 2005a). This ‘learning curve’ peaked at treatment night 7. We concluded that badgers developed CTA towards ziram-treated baits at this point. Ziram bait consumption was practically zero over the last 20 treatment nights (40 trial nights) and individuals avoided ziram baits, without sampling, for the last 12-22 treatment nights (24-44 trials nights). Observed changes in badger behaviour suggested that avoidance at a distance was facilitated by odour cues – most likely through second order conditioning. The important question arising from this was whether badgers would have continued to avoid untreated baits that produced the same cues.

Leading on from this, our next experiment was designed to test the potential role of an odour cue in CTA and specifically to establish whether untreated foods could be protected without being damaged through sampling (tasting) (Baker *et al*. 2007b). We conducted a three-phase conditioning trial using three treatments: (a) a combination of ziram (aversive agent) and clove oil (novel odour); (b) ziram; (c) clove oil. Again treatments were applied to biscuit bait. We tested two predictions: (1) ziram would produce learned aversion towards untreated foods; and (2) training with the ziram-clove combination would produce enhanced aversion towards untreated foods in the presence of a clove odour cue. Clove oil was selected to provide a strong odor cue that would be detectable at a distance. Incorporating such a cue might also facilitate using the odor to extend any protection to other areas or foods. Ziram did not produce learned aversion to untreated foods, but conditioning badgers with the ziram-clove combination produced learned aversion towards untreated foods in the presence of a clove odour cue. The clove control did not affect badger behaviour. See Figures 1-3 in Baker *et al*. (2007b). CTA studies with captive and wild mammals, other than rats, have demonstrated avoidance of untreated foods at a distance, and attributed this to conditioning of non-taste cues, but none has investigated which. Nicolaus and Nellis (1987) attempted, but failed, to train mongooses to associate one of two odours with an aversion to eggs. Captive animals continued to attack eggs regardless of the odour cue provided, while in contrast, free-ranging animals generalised their aversion to eggs treated with either odour. The authors attributed their findings to the captive conditions of the study, and to avoidance at a great distance, respectively. To our knowledge, ours is the only other study that has attempted to provide an odour cue for aversive foods. In contrast to the mongoose study, we conclude that conditioning badgers with a combined formulation of an aversive agent and an odour cue (instead of the aversive agent alone) produced enhanced aversion towards untreated foods in the presence of a clove odour cue. Our findings suggested that the aversion was mediated in some way via the odour cue.

The logical next step was a conditioning trial testing the combined formulation for the protection of model foods, e.g. maize cobs. In anticipation of this work, we first conducted a multi-choice dose-response trial to test the acceptability to free-ranging badgers of maize cobs treated topically with a range of ziram concentrations (Baker *et al*. 2005b). We considered this necessary because maize cobs are likely to differ from the biscuit bait used in previous trials in terms of consistency, familiarity to badgers and badgers’ motivation to feed. We successfully identified a minimum dose (1.3-1.5% [w/w]) that seemed to create either learned or direct aversion to treated baits among all participating badgers. We believe this to be the first investigation of the dose-dependent effects of an aversive agent on wild free-ranging mammals.

Our final badger CTA experiment to date tested CTA with a clove odour cue as a paradigm for protecting untreated model crop items (Baker *et al*. 2008). We conducted a three-phase conditioning trial using two treatments: (a) a combination of ziram (1.5% [w/w]) and clove oil; (b) clove oil. Following conditioning with the combined treatment, badgers avoided untreated maize cobs in the presence of a clove odour cue, whereas the clove control did not condition badgers.

This work has been an important step before proceeding to full-scale field trials for protecting crops on a wider scale. By using CCTV video and detailed behavioural observations of individual animals we were able to examine the conditioning mechanisms at work and so tailor each subsequent research stage accordingly. This iterative process has enabled us to move quickly from a broad initial remit to a potential application in four steps.

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