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TOWARDS PRACTICAL APPLICATION OF EMERGING FERTILITY CONTROL TECHNOLOGIES FOR MANAGEMENT OF ROSE-RINGED PARAKEETS

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Abstract Rose-ringed parakeets have recently become established in cities across Europe including London, where they are now commonly seen in parks and gardens. Concerns regarding impacts on native birds as well as noise and damage to horticultural interests, have prompted increasing interest in management of populations to reduce numbers. However, parakeets are also regarded by many people as a charismatic and colourful addition to our native fauna, and hence use of lethal methods is increasingly likely to meet with public opposition. We previously found that a cholesterol inhibitor, which has been used for control of feral pigeons, significantly reduced fertility rates in captive rose-ringed parakeets with no obvious negative effects on welfare. The effects are temporary but not species-specific, which means that targeted delivery systems are required before the method is likely to gain approval for use in the field in the UK. We developed and tested two types of weight-operated feeder using untreated test baits in captivity and then in the field. Feral parakeets successfully fed from the feeders, but non-target corvids and grey squirrels were also able to access the baits. Further development of species-specific delivery systems is required before non-lethal control of rose-ringed parakeets by using oral contraceptives is feasible.

Key words Ring-necked parakeet, *Psittacula krameri*, non-native species, human-wildlife conflicts.

INTRODUCTION

Rose-ringed parakeets (*Psittacula krameri*) are native to central Africa and Asia but through accidental and deliberate release, populations are now established in Europe, Japan, and the United States (Lever, 2005). As an invasive non-native species, the rose-ringed parakeet has raised conservation concerns, because the early breeding season and preference for established nest cavities places it in potential conflict with native cavity-nesting birds (Lever, 2005; Strubbe and Matthysen 2007, 2009a). In their native range, rose-ringed parakeets are considered serious agricultural pests (Ali and Ripley, 1969) and hence their population expansion is also of economic interest (Fera, 2010). In Europe however, rose-ringed parakeet populations are still largely concentrated in urban areas (Strubbe and Matthysen, 2009b) where they are common visitors to bird feeders in parks and gardens (Glue, 2002; Clergeau and Vergnes, 2011). Given the current and predicted impacts of rose-ringed parakeets, there has been considerable interest in their removal or control. Licenced shooting is permitted in England but primarily intended for crop protection and thus controversial in urban areas where justification may be more difficult to demonstrate. Non-lethal techniques, such as fertility control, potentially offer an alternative to culling, provided that they are effective, humane, safe and sustainable. We previously demonstrated that an orally administered cholesterol inhibitor 20, 25-diazacholesterol dihydrochloride (diazacon) was effective in reducing the productivity of rose-ringed parakeets in captivity (Lambert et al., 2010). Diazacon has also been found to be an effective contraceptive for the monk parakeet (*Myiopsitta monachus*) introduced to the United

States (Avery et al., 2006; Yoder et al., 2007; Avery et al., 2008). These promising results suggest that diazacon could potentially be used to help manage populations of invasive parrot species, including the rose-ringed parakeet. However, to avoid exposure to non-target species that could potentially be affected a reliable means of targeted application is required. We designed and tested two types of species-specific feeders in captive and free-living parakeets to determine (i) the ability of parakeets to feed from each design, (ii) the degree of species-specificity, to evaluate the feasibility of using this method to deliver contraceptive baits to the target species.

MATERIALS AND METHODS

Two novel types of custom-made feeders were designed (Figure 1). The first (lever-operated; LO) was based on the concept of the 'weighted door' design employed in food hoppers for grey squirrel control (Pepper and Currie, 1998). Instead of pushing against a weighted door to gain entry to a food hopper, the lever type feeder was operated by the weight of the target animal acting against a hinged and weighted lid via a perch and lever system. The weight on the lid was adjusted so that a downward force on the perch exerted by an adult parakeet of 125 g – 160 g average body weight (source: British Trust for Ornithology (2005) Ringing Scheme data) would be sufficient to raise the lid. The second design (springtype; SO) was based on a commercial cylindrical (tubular) birdseed feeder for perching birds but with a spring loaded outer tube restricting access for smaller perching birds by weight. Our designs were based on the types of garden bird feeders commonly used by small passerines and rose-ringed parakeets; we predicted that birds lighter than parakeets would be unable to operate the feeders, and we expected that larger garden birds would favour tray feeders and hence would not attempt to use our experimental feeders. Using untreated feed throughout, we trialled the feeders in four phases:

Trial of prototype feeders in captivity*:* First we tested the response of rose-ringed parakeets in captivity by placing two feeders of one design in each of six outdoor aviaries each containing seven parakeets; hence three aviaries had two lever-operated feeders and three aviaries had two spring-operated feeders. Aviaries were 7-10 m long x 3 m wide x 2.5 m high, constructed of rectangular wire mesh (12.5 x 25 mm) over a wooden frame with an earth or gravel floor; tree branches and wooden perches were added to simulate a natural environment. During the first week of the trial the feeders were locked open such that parakeets could feed freely; food takes from the feeders and spillage (collected in open trays beneath) were measured and observations of feeding behaviour by individual birds were made during one hour before dusk each day when parakeets were most active (Lambert et al., 2010). Data collected consisted of the length of time spent at each feeder, whether the parakeet was investigating or feeding during that visit, and interactions between individuals (wins/losses when birds tried to displace others from feeders or preferred perches) to determine social rank according to David's Score (Gammell et al., 2003). The feeders were then activated; observations of food takes and feeding behaviour continued for a further two weeks. Water, fresh fruit and normal maintenance diet (in open trays) containing sunflower, millet and hemp seeds were provided *ad-libitum* throughout the trial apart from in week 3 when the maintenance diet was removed during observation periods.

Outdoor pilot trial: Next we deployed four of the prototype feeders (two of each type) in an area where parakeets were not present to test the response of non-target species. The feeders were deployed in place of regular bird feeders filled with a weighed quantity of commercial bird seed mix and were locked open (pre-trial) for 8 days. The feeders were checked regularly (every 1-4 days), and the contents weighed and replenished if necessary. All test feeders were then closed (trial) for a further 7 days, they were then checked every 2-3 days, and the contents weighed if necessary. Bird visits to 2 of the feeders (one of each design) during the last 24 hours of the pre-trial phase, and the first 24 hours of the trial phase were recorded using a colour video camera linked to a time-lapse VCR to record number of species feeding and number of visits per species.

Main trial*:* We made larger feeders to increase capacity (but to the same designs and weight sensitivity as previously), and deployed them at 12 sites (0.35 km – 28 km apart) where rose-ringed parakeets occurred in Surrey (*n* = 6; 4 LO, 2 SO), Berkshire (n = 4; 1 LO, 3 SO) and Buckinghamshire (n = 2; 1 LO, 1 SO). One trial site was on farmland at the Animal and Plant Health Agency in the county of Surrey where rose-ringed parakeets were known to regularly visit bird feeders, the others were private gardens in sub-urban areas likely to be visited by rose-ringed parakeets (parakeets were known to have visited several of these gardens the previous winter). LO feeders were fixed to the top of a 2m fence post; SO feeders were suspended from a commercial bird feeder hanger at a similar height. Feeders were locked open from mid-November 2009 until 9th February 2010; this time was chosen as the likely time for delivery of contraceptives in advance of the early (late winter) egg-laying period (Lambert et al. 2009). Feed take was measured 1-2 times per week, camera traps ((DGS-I60, MFH-I-40 (Moultrie, Calera, Alabama) or RC60 (Reconyx, Wisconsin, USA)) were used to monitor bird activity (species visiting, whether they successfully fed) for the final 20 days of this pre-bait period and for the remainder of the trial. Half of the feeders (3 of each type) were activated for 21 days; the treatments were then reversed and observations continued for up to 27 days. Feeders were placed away from fences and mature shrubs and trees to deter grey squirrels (*Sciurus carolinensis*) from feeding; a baffle was also added to each feeder support to deter access by squirrels. A tray was placed below each feeder to measure spillage. Half of the feeders (3 lever-operated and 3 spring-operated) had open trays so that non-target birds were allowed to feed, and hence their feeding behaviour could be monitored. The remaining feeders had mesh covers so that non-target birds could not remove the spillage, hence we could record the weight of spilled food

Follow-up trial: As anecdotal evidence from the previous trial suggested that proximity of the feeders to trees or shrubs might affect likelihood of parakeets using the feeders, we investigated the effect of feeder placement with a further short trial. Feeders were deployed at 6 sites (3 Berkshire, 3 in Buckinghamshire); 3 were new sites, 3 were sites used in the main trial. The feeders (all SO type) were placed near to (within 5m) mature trees, shrubs or other structures that might enable parakeets to land in groups (rather than previously where feeders were placed in open ground to deter grey squirrels. The trial lasted a total of 49 days; all feeders were first locked open and then (after 2 weeks) activated, otherwise the trial followed the same protocol as the main trial.

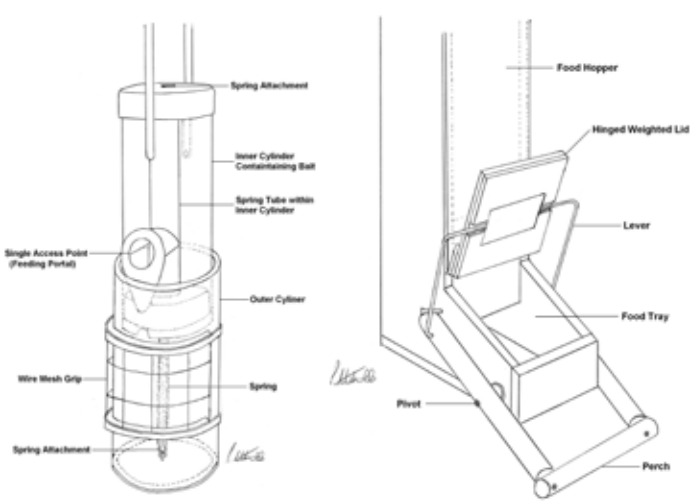

Figure 1. Two types of custom-made bird feeders designed for species-specific presentation of feed to rose-ringed parakeets (drawings by Phil Aldwinckle).

RESULTS

***Trial of prototype feeders in captivity**:* Captive birds quickly learned to use the feeders. The mean daily feed take (shelled peanuts) was greater for the lever-operated (Figure 2). Total bait uptake from the six spring-operated feeders was 386.8 g, spillage was 70.5 g (18.2%), hence 316.3 g were consumed; this was equivalent to an average of 1.4 g per bird per day. Total bait uptake from the six lever-operated feeders was 1752.4 g, spillage was 525.7 g (30%), hence 1226.7 g were consumed and equivalent to an average of 5.7 g per bird per day. Observations of feeding behaviour indicated no significant correlation between David's Score and number of feeding visits to either the lever-operated feeder (Spearman's rank correlation coefficient *rho* = -0.353, *P* = 0.123) or spring-operated feeder (*rho* = 0.107, *P* = 0.948) indicating that feeders were not monopolised by individual birds.

***Outdoor pilot trial**:* During the pre-trial phase, the feeders were visited by 5 species. Three species visited both feeders; blue tit (*Cyanistes caeruleus*), great tit (*Parus major*), tree sparrow (*Passer montanus*). A further two species visited the lever-operated feeder; greenfinch (*Carduelis chloris*) and robin (*Erithacus rubecula*). None of the species visiting the feeders were able to access the contents during the trial phase (Table 1).

***Main trial**:* A total of 45,349 g of feed was taken between feeder deployment in mid-November and the end of the trial 136 days later; 22,190 g from spring-operated feeders and 23,159 g from lever-operated. Food take for the 29 days to 30th December was 10,435 g, the bait uptake for the following 29 days was 9,992 g; this suggested that bait takes had stabilised over the first two weeks of the pre-trial period in late November. The total amount of spilled bait recorded during the entire trial from all feeders was 772.8g; the majority of this (742.8 g) was found in the mesh-covered trays representing 2.48% of the food takes from those six feeders. When switched to weight-activated mode, average daily food takes were reduced by 28.4% (from 218.4 g to 156.4 g) for spring-operated feeders and by 73.4% (from 243.9 g to 65.0 g) for lever-operated feeders. Between 20th January (when camera observations started) and the end of the trial 2,783 visits to the feeders by rose-ringed parakeets and 13 non-target species were recorded; 2,649 (95.2%) visits by non-targets and 134 (4.8%) by rose-ringed parakeets (Table 2). A total of 622 feeding visits were recorded when feeders were in weight-activated mode; five by Eurasian jay (*Garrulus glandarius*), 85 by Eurasian jackdaw (*Corvus monedula*), 511 by grey squirrel and 21 by rose-ringed parakeets (jays and squirrels fed from the lever-operated feeders, jackdaws and rose-ringed parakeets fed from the spring-operated feeders).

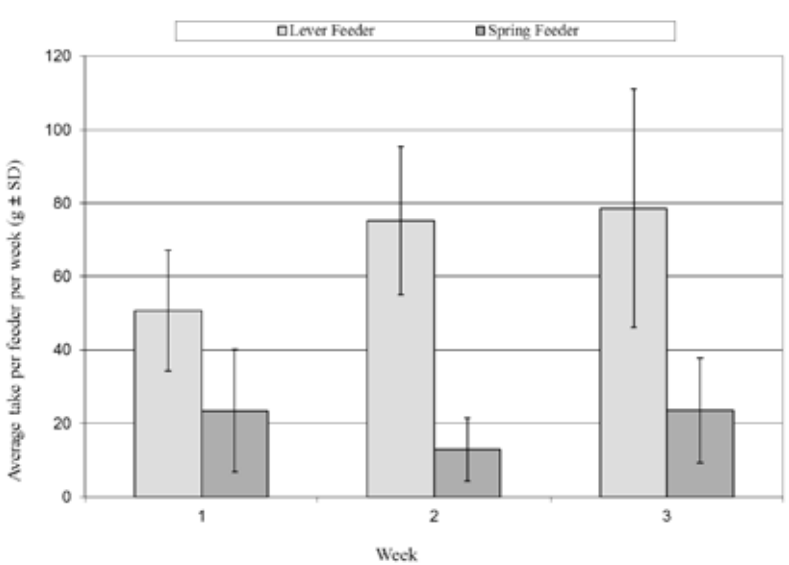

Figure 2. Mean peanut takes from two types of feeders presented to 42 rose-ringed parakeets in captivity (six aviaries, three with two lever-operated feeders and three with two spring-operated feeders). Alternative food was provided throughout except in week 3 when it was removed for one hour each day.

Table 1. Data from the outdoor pilot trial of two novel feeder designs to determine the response of non-target passerines (rose-ringed parakeets were not present in the study area). Four feeders (two spring-operated and two lever-operated) were deployed for 8 days locked open (the pre-trial phase) and 7 days closed (the trial phase). Visits to two of the feeders were analysed using time lapse video during the last 24 hours of the pre-bait phase, and the first 24 hours of the trial phase.

	Pre-trial period (8 days)		**Trial period (7 days)**	
	Spring	**Lever**	**Spring**	**Lever**
Number of species visiting	3	5	3	5
Number of visits	109†	134‡	57	42
Total visit time (s)	1:30:44	1:38:22	0:08:07	0:07:08
Median visit time (s)	9	12	5	7
Percent successful visits	85%	97%	0%	0%
Daily bait takes per feeder (g ± S.E.)	27.3 (± 3.2)	49.7 (± 3.6)	0.1 (± 0.1)	0.0 (± 0.0)

†Includes 7 visits by small passerines that could not clearly identified from the video footage ‡ Includes 5 visits by small passerines that were not clearly identified from the video footage.

Table 2. Visits to weight sensitive feeders (six lever-operated, six spring-operated) deployed at study sites in south eastern England during November 2009 – March 2010 (parenthesis indicates the number of visits where food take from the feeder was observed).

	Open (pre-trial)		**Activated (trial)**		
	Lever-operated	**Spring-operated**	**Lever-operated**	**Spring-operated**	**Total**
Blackbird *Turdus merula*	1				1
Blue tit *Cyanistes caeruleus*	16 (2)	13 (5)		1	30
Collared dove *Streptopelia decaocto*				3	3
Feral pigeon *Columba livia*	1				1
Great spotted woodpecker *Dendrocopos major*	1 (1)	6 (1)		2	9
Great tit *Parus major*	28 (8)	20 (4)	4	4	56
Jay *Garrulus glandarius*	373 (257)	13 (2)	14 (5)	3	403
Jackdaw *Corvus monedula*		303 (130)		326 (85)	628
Magpie *Pica pica*		64 (27)		2	66
Pheasant *Phasianus colchicus* [1]		2		1	3
Robin *Erithacus rubecula*	1	1			2
Rose-ringed parakeet *Psittacula krameri*	2	87 (23)	1	44 (21)	134
Grey squirrel *Sciurus carolinensis*	806 (683)		571 (511)		1377
Wood pigeon *Columba palumbus*	58 (2)		11		69
Total	1287	509	601	386	2783

[1] On top of feeder

***Follow-up trial**:* Non-target birds did not feed from the spring-operated feeders (lever-operated feeders were not used for this trial as the main trial demonstrated that rose-ringed parakeets did not feed from this type in the field). Rose-ringed parakeets visited 5/6 feeders (38 visits in total) during the pre-trial phase and fed 19 times (a further 4 visits were putative feeding visits) (Table 3). During the trial phase, rose-ringed parakeets visited 2/6 feeders made 6 visits and fed 3-4 times. The following 8 non-target species visited the feeders during the pre-trial phase (number of visits in brackets): blue tit (229), great tit (197), greenfinch (12), jay (4), robin (4), coal tit (*Periparus ater*) (2), great spotted woodpecker (2), and nuthatch (*Sitta europaea*) (1). There were 9 visits by birds that could not be identified from the photographic records. No non-target birds accessed the feed during the trial phase. Squirrels visited all six feeders during either the pre-trial or trial phase; they successfully fed from two feeders during the trial phase.

Table 3. Visits to 6 spring-operated weight sensitive feeders in Surrey & Berkshire between 27 January and 16 March 2011. Figures in parenthesis are additional possible feeding visits where it was not clear from the photograph whether the animal had fed or not.

		Open (pre-trial)	Activated (trial)
Rose-ringed parakeets	Visits	38	6
	Feeding visits	19 (+4)	3
	Feeding at spillage tray	0	0
Other birds	Visits	462	8
	Feeding visits	266 (+5)	0
	Feeding at spillage tray	4	0
	Total visits	500	14
Grey squirrels	Visits	31	80
	Feeding visits	18	52
	Feeding at spillage tray	0	0

DISCUSSION

Orally administered cholesterol inhibitor 20, 25-diazacholesterol dihydrochloride (diazacon) is effective in reducing the productivity of rose-ringed parakeets in captivity (Lambert et al., 2010). As an alternative to culling, fertility control has the potential to offer a long-term, effective and more socially acceptable means of reducing the size and growth of overabundant wildlife populations (Barlow, 2000; Smith and Cheeseman, 2002; Massei and Cowan, 2014). Diazacon affects the fertility of other species of mammals and birds, albeit temporarily (Fagerstone et al., 2010) hence targeted delivery is needed to achieve species-specificity.

Our trials with captive birds demonstrated that rose-ringed parakeets successfully used both novel feeder types during the pre-trial (locked open) and trial (activated) phase. Indeed, the amount of bait consumed from each feeder did not differ between the three weeks of the trial, suggesting that bait take was not reduced during the trial phase when the birds had to use the weight-operated mechanisms, and did not increase when alternative food was temporarily removed. Individual parakeets made up to 76 visits to feeders during the 3 weeks of the trial phase, suggesting a high level of interest in the feeders, although in free-feeding trials monk parakeets (*Myiopsitta monachus*) appeared to self-regulate intake of diazacon baits (Yoder et al., 2007). Uptake from the lever-operated design was significantly higher than from spring-operated feeders, indicating that this design might be more effective in delivering baits to a higher number of birds.

Rose-ringed parakeets did not feed from lever-operated feeders in the field, but they successfully fed from one of the spring-operated feeders during the main trial, however the number of visits (both during the pre-baiting and trial phases) was lower than expected. Rose-ringed parakeets were recorded at only five of the 12 sites during the trial phase, and at three of those sites they were recorded on just one occasion. During the pre-bait phase, two feeders were removed from trial sites which had not received parakeet visits and moved to gardens where parakeets regularly visited bird feeders, but this still did not greatly increase the number of visits. It is possible that the problem may have been feeder placement. Feeders were placed away from mature shrubs, trees and fences in an attempt to limit access to grey squirrels. However, this may have also discouraged the target birds; preliminary observations in the urban gardens used for the trials suggested that rose-ringed parakeets may have avoided the exposed position of the feeders, perhaps due to potential risk of attack from predators. A previous study of garden bird feeder positioning found that food consumption at feeders adjacent to cover was approximately double that of feeders 7.5 m from cover (Cowie and Simons, 1991). The follow-up trial, where the feeders were placed within 5m of mature shrubs, trees and other structures did appear to increase the number of visits by rose-ringed parakeets, but grey squirrels, which had not successfully fed from the spring-operated feeders during the main trial, did feed during the trial phase of 2011 experiment. Exposure of grey squirrels could potentially be reduced or prevented by further baffles or other devices to prevent access to feeders, although ongoing interest in use of diazacon to control non-native grey squirrels may negate these concerns (Mayle et al., 2013). There was also some evidence from this study that parakeets found it difficult to land on the feeders. In captivity, the lever-operated feeders were attached to the sides of the aviaries (most parakeets tended to land on the mesh cage sides and climb across to the feeder, rather than land directly on the perch) and the spring-operated feeders were suspended next to branches; the birds usually landed on the branch and then climbed onto the feeder. However, the low number of rose-ringed parakeets recorded at the study sites during both field trials suggests that residential suburban gardens are probably not suitable sites for placement of bait delivery systems during autumn and winter. Future work should evaluate the factors that affect bait uptake from bird feeders by parakeets to optimise the targeting a larger number of rose-ringed parakeets, particularly in areas where they may be attracted to preferred food sources (for example rural areas where vulnerable soft fruit is extensively grown) or near to roost sites.

In the outdoor pilot trial, both feeder designs were effective in excluding non-target species. However in the main trial outdoors, jackdaws, which had not visited the feeders during the outdoor pilot trial successfully fed from one spring-operated feeder. This feeder was placed in a rural environment, which is not representative of the urban and sub-urban sites where the other five spring-operated feeders were placed. This site also differed in bird assemblages compared to other sites, receiving the second highest number of pre-trial visits (only one lever-operated feeder received more) and the highest overall number of species during the pre-trial phase. Of the nine species recorded at the feeder during the pre-trial phase, all but jackdaws were excluded during the trial phase. Great spotted woodpeckers, one of the species present at this site but not commonly present in urban or sub-urban gardens, had damaged the feeder baffle during the pre-trial phase; although the baffle was repaired, this may have made it easier for jackdaws to access the feeder. Despite jackdaw numbers increasing at the national level, the use of gardens by this species has declined in recent years and is also seasonal (Cannon et al., 2005); this would potentially allow deployment of parakeet feeders at times when jackdaws are least likely to occur in gardens. Nonetheless, expansion of rose-ringed parakeets from urban into rural areas would doubtless prompt interest in controlling populations in agricultural contexts where exclusion of non-target species is likely to be particularly challenging; further development of feeders for targeted delivery of fertility control baits is therefore likely to be required.

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