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DO COLOURS THAT DETER BIRDS AFFECT CEREAL BAIT ACCEPTANCE BY POSSUMS (*TRICHOSURUS VULPECULA*)?

Summary: Poisonous baits used for pest control in New Zealand commonly contain green dye and cinnamon oil to make them less attractive to birds. Research aimed at reducing the impact of poison based pest control on birds has shown that some birds are initially deterred from feeding on blue or, to a lesser extent, green coloured food and are attracted to yellow or red food. We determined whether colours that deter or attract birds affected the acceptance of non-toxic and toxic cereal baits by captive brushtail possums (*Trichosurus vulpecula*). Individual possums were offered, daily, a choice between a standard green dyed non-toxic cereal bait and either a blue dyed (17 possums) or yellow dyed non-toxic bait (16 possums) for 10 days. Following this, for the first group of 17 possums, 1080 toxin was added to either the green bait (9 possums) or blue bait (8 possums) and possums were offered the green versus blue choice again. Two additional groups that had not previously been fed cereal baits were also given a choice between blue and green baits, one of which was toxic. All possums offered non-toxic bait ate less on the first day of presentation than on subsequent days. There was no difference in acceptance of either blue or yellow coloured non-toxic bait compared to the standard green non-toxic bait on any days. Bait colour appeared to be unimportant in cereal bait choice and did not deter possums from eating any of the baits. The addition of toxin to baits did not significantly alter bait choice in any groups, although some individuals which had no previous experience with baits ate more toxic than non-toxic bait. These data suggest that adding a stronger bird deterring colour (i.e., blue) to poisonous baits is unlikely to adversely affect the acceptance of baits by possums.

Keywords: Brushtail possum; *Trichosurus vulpecula*; colour acceptance; baits; New Zealand birds; non-target species.

Introduction

New Zealand's most serious vertebrate pest, brushtail possums (*Trichosurus vulpecula* Kerr) are extensively controlled using poisonous baits. These baits are sometimes consumed by non-target species, particularly birds (Spurr, 1993). In order to reduce the number of non-target deaths, several measures are routinely employed to deter birds from feeding on baits. Cinnamon oil (Pracy, Robertson and Udy, 1982) and green dye (Caithness and Williams, 1971) are added to baits as deterrents and attractive lures, such as raspberry essence, have been banned. While this reduces the number of birds that eat baits, it does not eliminate all deaths. Spurr (1993) found that the majority of New Zealand bird species tested (including North Island weka (*Gallirallus australis greyi*)[1] , red-crowned parakeets (*Cyanoramphus novaezelandiae novaezelandiae*), North Island kokako (*Callaeas cinerea wilsoni*) and North Island saddlebacks (*Philesturnus carunculatus rufusater*)) sampled sufficient quantities of green dyed and cinnamon flavoured bait to have been poisoned if the baits had been toxic. Hickling (1997) also found that North Island kaka (*Nestor meridionalis septentrionalis*) were not deterred by green dyed cinnamon flavoured baits until after they had sampled the bait. More effective bird deterrents that do not reduce the bait acceptance of pest species are required.

Changing the colour of poisonous baits from green to a more deterrent colour may be a cheap but effective way of reducing lethal bait sampling by birds (Hartley *et al*, 1999). Hartley *et al*. (1999) found that North Island weka and North Island robin (*Petroica australis longipes*), species which are at risk during poisoning operations (Eason and Spurr, 1995), discriminate between food items on the basis of colour. Both species are mildly deterred by green food items, but more strongly deterred by blue-coloured food. Yellow or red-coloured foods are preferred by North Island weka and North Island robin, and have also been shown to be eaten by other birds (Caithness and Williams, 1971). While the deterrent effect of bait colour is limited to the first day or two of exposure for weka (Hartley *et al*, 1999), this may be sufficiently long to reduce non-target bird deaths.

[1]Bird nomenclature follows Turbott (1990)

This research aimed to determine: (1) whether the acceptance of non-toxic and toxic baits by possums was affected by bait colour; and (2) whether baits containing a bird deterrent (blue colour) were eaten by possums as readily as standard green baits.

Methods

Animals and housing

Forty-nine wild-caught possums were individually caged in a quarantine facility for a six-week adaptation period, during which animal health checks were completed. They were then moved to an experimental housing facility where they were maintained on a reverse 12:12 h light/dark cycle and trained to eat daily within a 30 min period, beginning at the start of the dark cycle (1000 h). Each possum was fed daily with a cereal-based mash diet (possum pellets, Northern Rolling Mill, Auckland, New Zealand, and water at a ratio of 1:1.5 wt/wt) and an apple at 1430 h. Two trays of 200 g mash were presented to each possum daily. The trays of mash were presented in two steel tray holders attached to the front wall of each cage, 370 mm apart and 40 mm from the left or right wall of the cage. This enabled us to feed each possum on both the left and right side of the cage. Water was available *ad libitum* from nipple drinkers. Throughout the experiment the daily mash consumption of each possum was recorded by subtracting the post-feeding weight of each tray of mash from the weight of each mash tray offered at the beginning of the feeding period. All experimental procedures were approved by the Ruakura Animal Ethics Committee.

Baits tested

The cereal baits tested were non-toxic and toxic (0.15% sodium monoflouroacetate; 1080) RS-5 baits manufactured by Animal Control Products Ltd (Waimate, New Zealand). The non-toxic baits contained no dye and the toxic baits contained 0.01% Special Green V200A dye (Bayer NZ Ltd, Auckland) when purchased. No baits contained lure throughout the experiment. We dyed the non-toxic baits blue, green or yellow and the toxic baits blue or green over the existing dye in the bait. The colours used in the experiment were matched, by visual comparison and by using the same dyes, to those colours found to be avoided and preferred by birds in colour preference studies (Hartley *et al*, 1999). The non-flavoured powdered food dyes (Bush Boake Allen [New Zealand] Ltd, Auckland) were mixed with water (2% wt/wt) and the baits were individually dyed by surface coating them with the dye solution 24 h prior to testing and allowing them to dry at room temperature.

Experiment 1: Non-toxic baits

Thirty-three possums were allocated to two treatment groups balanced for age, sex, body mass and food consumption. The acceptance of baits by possums was determined over a 10 day period by offering each possum in the two groups a daily choice between either a blue and a green bait (17 possums; 6 females; mean age of 2.5 ± 0.2 y; mean body mass of 2.4 ± 0.1 kg) or between a yellow and a green bait (16 possums; 5 females; mean age of 2.6 ± 0.3 y; mean body mass of 2.4 ± 0.1 kg). The single baits were placed on the top of each tray of mash during the daily 30 min feeding sessions, with a different colour on each side. On each day, the two baits offered were the same mass and were equivalent to at least an LD_{50} sized bait. Colours alternated between the left and right food trays daily to overcome any side bias. Each bait was weighed before and after the feeding period to determine the total mass of bait consumed by each possum. Control baits placed in mash trays that were not fed to possums were also weighed before and after feeding to determine moisture uptake by the baits during the feeding period. The post feeding bait masses of all possums were then corrected for moisture uptake.

Experiment 2: Toxic baits

The 17 possums that were pre-fed with blue and green non-toxic baits in experiment 1, were offered the same coloured baits, but either the blue bait (8 possums; 3 females; mean age of 2.5 ± 0.4 y; mean body mass of 2.4 ± 0.1 kg) or green bait (9 possums; 3 females; mean age of 2.6 ± 0.4 y; mean body mass of 2.5 ± 0.2 kg) was toxic (0.15% 1080). Two additional groups that had previously not been fed cereal baits (naive groups) were also offered the choice between blue and green baits, with either the blue bait (8 possums; 2 females; mean age of 2.6 ± 0.5 y; mean body mass of 2.5 ± 0.2 kg) or green bait (8 possums; 3 females; mean age of 2.5 ± 0.4 y; mean body mass of 2.4 ± 0.1 kg) containing 1080 at 0.15%. The baits were presented on top of the mash, as in experiment 1, with both baits of the same mass (at least an LD_{50} for each animal). Possums were offered the choice between non-toxic and toxic baits for one day, but any possum that did not consume toxic bait was fed the same bait choice again on the following day.

Analyses

All data analyses were performed using the generalised linear mixed model (GLMM) in the Genstat 5 (release 3.1; Lawes Agricultural Trust, Rothamsted Experimental Station, Hertfordshire, U.K.) statistical software. In experiment 1, consumption of blue or yellow bait, as a percentage of total bait eaten, was calculated by dividing the mass of blue or yellow bait eaten by the total mass of bait eaten on that day. This gave a relative measure of blue or yellow bait consumption compared to green bait consumption for each possum on each day. The proportion of blue or yellow bait eaten by possums was then compared between colours and days using a repeated measures analysis of variance. As a small number of possums ate all of the bait they were offered on some days, the data were transformed using the arcsin transformation. Animals which ate no bait throughout the trial were excluded from the analysis.

In experiment 2, the quantity of blue bait eaten and the quantity of toxic bait eaten, both calculated as a proportions of total bait consumption for each animal, were compared between pre-fed and naive possums for each possum group (blue toxic or green toxic) using 2-factor analysis of variance. Again, the data were transformed using the arcsin transformation and possums which ate no bait were excluded from the analysis. Due to heteroscedacity, Satterthwaite's (1946) method was used to estimate the degrees of freedom for the 2-factor analyses of variance.

The total quantity of bait eaten (regardless of colour or toxicity) by the pre-fed and naive possums in experiment 2 was compared using a single-factor analysis of variance. This method of analysis was also used to compare the total quantity of bait eaten by the pre-fed possums on day 1 of experiment 1 with the total quantity eaten by naive possums in experiment 2. All data are quoted as means ± standard error.

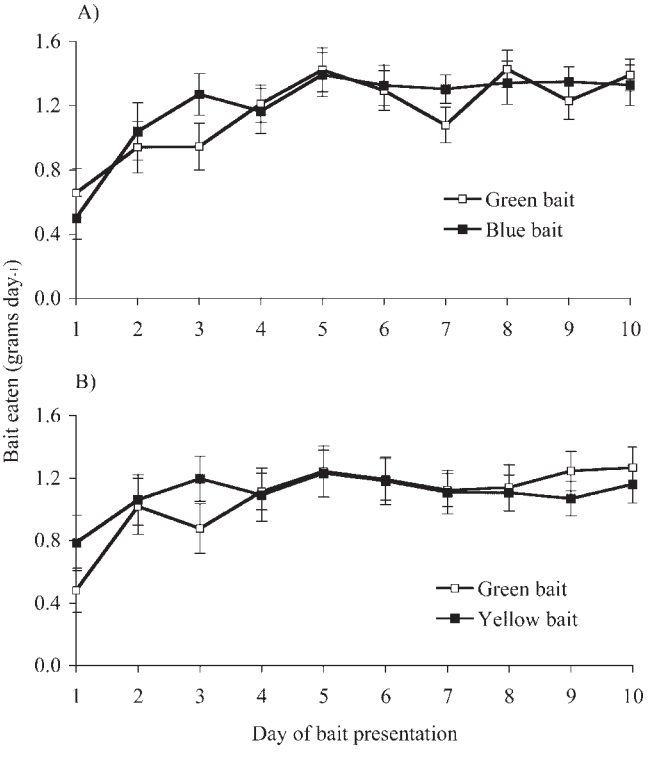

Figure 1: *Mean weight (g ± S.E.) of each bait colour eaten daily over a 10 day feeding period by possums fed a choice between: A) green and blue non-toxic baits; or B) green and yellow non-toxic baits.*

Results

Experiment 1: Non-toxic baits

On the first day of bait presentation, seven of the 33 possums tested did not eat bait of any type (4 from the blue versus green bait group; 3 from the yellow versus green bait group). Three of these possums (1 from the blue versus green group; 2 from the yellow versus green group) did not eat any baits throughout the experiment. For the animals that ate baits, all ate less on the first day of presentation than on subsequent days ($F(3.4, 95.6) = 16.49$, $P < 0.001$; Fig. 1). The proportion of each bait type eaten was not affected, in either the blue versus green bait group or the yellow versus green bait group, by the colour of the bait ($F(1, 28) = 0.10$, $P = 0.76$) or the interaction between bait colour and the day of presentation ($F(3.4, 95.6) = 0.57$, $P = 0.82$). Overall, 51 ± 9% of total bait eaten was blue in the blue versus green bait group and 52 ± 8% of total bait eaten was yellow in the yellow versus green bait group.

Experiment 2: Toxic baits

When offered a choice between toxic and non-toxic baits of different colours, 6 possums (2 pre-fed possums and 4 naive possums) ate no baits. These animals were re-offered the baits on the following day and 3 possums again did not eat them. For the possums which ate baits, pre-fed animals ate significantly more bait (mean of 3.2 ± 0.2 g) than naive possums (mean of 1.9 ± 0.2 g; $F(1, 26) = 33.81$, $P < 0.001$). However, the quantity of bait eaten by naive possums did not differ from that eaten at first exposure (Experiment 1) by the pre-fed group (mean of 1.6 ± 0.2 g; $F(1, 45) = 1.50$, $P = 0.23$).

The colour of the toxic bait (blue or green; $F(1, 26) = 1.55$, $P = 0.22$), the possum group (pre-fed or naive; $F(1, 26) = 0.56$, $P = 0.46$) or the interaction between the two (toxic colour and possum group; $F(1, 26) = 0.51$, $P = 0.48$) did not affect the mean consumption of blue bait (as a proportion of total bait consumption; Table 1). The proportion of total bait eaten that was blue was 52 ± 4% for pre-fed animals and 57 ± 3% for naive possums.

The proportion of total bait eaten that was toxic (Table 2) was not affected by the colour of the toxic bait (blue or green; $F(1, 26) = 0.68$, $P = 0.42$), the possum group (pre-fed or naive; $F(1, 26) = 0.50$, $P = 0.49$) or the interaction between the two (toxic colour and possum group; $F(1, 26) = 0.54$, $P = 0.47$). However, three naive possums that were offered a choice between toxic blue bait and non-toxic green bait, ate only toxic blue bait.

Table 1: *Mean consumption of blue bait (as a percentage (± S.E.) of total blue and green bait consumed) for pre-fed and naive possums given a choice between blue and green baits that were toxic or non-toxic.*

	% blue bait (± S.E.) from total bait eaten	
Group	Blue toxic	Blue non-toxic
Pre-fed	49.1 ± 6.9	53.2 ± 8.0
Naive	62.2 ± 8.0	51.5 ± 8.8

Table 2: *Mean consumption of toxic bait (as a percentage (± S.E.) of total toxic and non-toxic bait consumed) for pre-fed and naive possums given a choice between toxic and non-toxic baits of different colours.*

	% toxic bait (± S.E.) from total bait eaten	
Group	Blue toxic	Green toxic
Pre-fed	49.1 ± 6.9	46.8 ± 8.0
Naive	62.2 ± 8.0	48.5 ± 8.8

Discussion

In this experiment, several possums (22%) avoided eating baits on the first day of exposure, but subsequently readily consumed all bait they were offered. This rejection of baits when first exposed to them is known as neophobia, an innate initial avoidance of novel food items (Prakash, 1988). Neophobia has been described previously in possums and suggested as one of the factors that may lead to sub-lethal poisoning (O'Connor and Matthews, 1996). Morgan (1990) found that only 5% of possums avoid non-toxic unlured cereal baits when they first encounter them, but 34% of possums avoid toxic baits of the same type. In the present experiment, more possums avoided non-toxic baits at first exposure than in Morgan's (1990) study, but a similar level of avoidance of toxic baits (25% of possums in this study) was observed. Others (e.g., O'Connor and Matthews, *in prep.*) have found that 0 - 20% of naive possums avoid toxic baits at first exposure. While the reasons for the observed difference in non-toxic bait acceptance are uncertain, it is possible that the cereal-based mash diet fed to possums in this study altered their acceptance of non-toxic baits.

A small number of possums avoided all baits they were offered throughout the experiment. These animals did not sample any bait, despite the fact that the baits were offered on top of their normal food. Bait avoidance (or shyness) over an extended time

period could be due to previous sub-lethal poisoning, leading to a learned aversion to the bait type that they were poisoned with (O'Connor and Matthews, 1996). It is unlikely, however, that any of the possums used had developed learned bait aversions prior to the experiment, as they were all captured from a population which had not previously been subjected to poison baiting. Some possums may always avoid cereal baits, even when they encounter them repeatedly.

Bait colour did not appear to be an important factor in bait acceptance by possums. None of the possums appeared to be repelled by the blue, green or yellow colours used. As there was no difference in acceptance of differently coloured baits, we do not know if the possums could discriminate between the baits on the basis of colour. Morgan, Morriss and Hickling (1996) found that possums chose green dyed baits when offered a choice between green and undyed cereal baits after developing a learned aversion to the green dyed bait. However, their study did not determine whether the discrimination was due to the bait colour or some other property of the dye (e.g., smell, taste) causing a difference between the baits.

Possums offered a choice between toxic and non-toxic bait ate both bait types readily. This contrasts with the findings of Morgan (1990), who found that significantly more possums avoid toxic baits than non-toxic baits, unless the baits contain a masking flavour. Moss, O'Connor and Hickling (1998) also found that most possums fail to detect 1080 in cereal baits lured with cinnamon. Despite the fact that all baits in our study were unlured, the possums either did not detect the 1080 in the toxic bait or, if they did detect it, were not deterred from eating it. The cereal-based mash that possums were fed prior to being offered the baits may have had a prefeeding effect, reducing the avoidance of toxic bait. Interestingly, three naive possums in this study, fed a choice between toxic blue and non-toxic green baits, ate only toxic bait. It is possible that these possums found either the toxic bait or the blue colour more acceptable in these baits than the non-toxic green coloured alternative bait. However, the difference in acceptance may be coincidental, as these possums also ate mash only from that side of their cage on the test day, suggesting they may not have investigated the green bait.

From a possum control perspective, these results are encouraging. Hartley *et al*. (1999) found that blue-coloured food was less attractive to weka and robins than foods coloured differently. We have found that using blue colour in poisonous baits is unlikely to adversely affect bait acceptance by possums. Therefore, through the use of blue coloured baits, it may be possible to reduce bird deaths without reducing the efficacy of possum control operations. Further research should be aimed at determining the deterrent effect of blue colour in baits to a range of bird species that are at risk. The effect of blue colour on bait acceptance by rats (*Rattus* spp.) should also be determined, as they are often a secondary target during possum control operations (Innes *et al*, 1995). If bait acceptance of rats is not reduced and other bird species are not attracted by blue baits, changing bait colour from green to blue may provide more effective protection than is currently available for native birds during poisoning operations.

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