KEA REPELLENT FOR CEREAL BAIT: A CAPTIVE STUDY USING ANTHRAQUINONE

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INTRODUCTION

Aerial 1080 (sodium fluoroacetate) operations, using cereal baits, are used over much of New Zealand as an effective tool for reducing mammalian pest populations of brushtail possums (Trichosurus vulpecula) and ship rats (Rattus rattus) (Eason et al. 2011; Kemp et al. 2019) for the benefit of native biodiversity and to reduce the incidence of bovine tuberculosis.

The kea (Nestor notabilis) is a highly intelligent, charismatic, large parrot that is endemic to the South Island of New Zealand (Orr-Walker et al. 2015; Van Klink & Crowell 2015; Kemp et al. 2019). Kea are omnivorous and forage primarily on the forest floor (Greer et al. 2015), where aerial 1080 baits are typically distributed to target possums and rats. Kea are also highly curious birds that often investigate novel food objects (Kemp et al. 2019), thus they are at risk of direct poisoning by 1080 during aerial operations (Orr-Walker & Roberts 2009). Where kea have been killed by 1080 poisoning, the subsequent productivity of the local kea population generally outweighs these losses, albeit with some exceptions, as a result of the reduced predation pressure (Kemp et al. 2018).

Zero Invasive Predators Ltd (ZIP) is planning to implement a modified aerial 1080 prescription known as '1080 to Zero' (Bell 2017) at a 12,000 hectare site in South Westland, known as the Perth River valley (43.2616° S, 170.3590° E), as part of a wider programme of work to develop a Remove and Protect model of predator control (Bell 2019). The kea population at the Perth valley site has been recently estimated at between 75-100 birds (I. Graham, DOC, pers. comm. 2018).

One potential strategy for reducing consumption of cereal bait by kea is through the addition of a bird repellent to the bait (Orr-Walker et al. 2012; Cowan et al. 2016; Crowell et al. 2016). Previous captive trials have examined the potential of the bird repellent anthraquinone to substantially reduce consumption and then deter kea from cereal bait (Orr-Walker et al. 2012; Reardon 2014). However, a viable solution was not found for a variety of reasons, e.g. concern for aversion in target species (Cowan et al. 2015), and inconsistencies in texture and colour (Reardon 2014).

OBJECTIVE

In this study we examine the potential for repeated exposures of captive kea to non-toxic prefeed cereal baits laced with a concentration of 2.7% anthraquinone by weight to reduce consumption of standard bait (i.e. not laced with anthraquinone) upon subsequent presentation, through a conditioned learned aversion.

We tested whether it was possible to create this aversion in two bait matrices, i.e. Wanganui #7 (W#7) and RS5, because each of these is planned to be used as part of the planned 1080 to Zero operation in the Perth River valley. We exposed the captive birds to both bait types in a similar order to that planned for the operation.

If conditioned learned aversion by kea reduces consumption of cereal baits, then this may help to reduce the risk of mortality of kea in the planned Perth River valley 1080 to Zero operation. Learned aversion could also be a method that can be applied in standard aerial 1080 operations in kea habitat.

TRIAL DESIGN/METHODS

Anthraquinone as a Bird Repellent

Anthraquinone is a widely-used secondary repellent for birds (Werner et al. 2011; Clapperton et al. 2014; Cowan et al. 2016). Once ingested, the repellent results in mild gut discomfort, leading to gagging behaviour, and sometimes vomiting (Werner et al. 2011). This is in contrast to the function of primary repellents that rely on direct cues such as flavour, smell (e.g. d-pulegone) (Cowan et al. 2015) and colour.

Bird repellents have been trialled previously with both captive and wild kea in an attempt to reduce consumption of cereal bait (Orr-Walker et al. 2012; Reardon 2014; Van Klink & Crowell 2015). However, these trials have been confined to low concentrations of repellent that remain palatable for pest species because the repellent was intended to be included in the toxic baits (rats had shown a high aversion to anthraquinone-laced cereal baits) (Orr-Walker et al. 2012; Cowan et al. 2015; Crowell et al. 2016).

The concentration of anthraquinone used in this ZIP trial is higher than previously tested (Orr-Walker et al. 2012; Reardon 2014), because the intended strategy is for repellent bait to be sown above the upper boundary of the area that will be treated with 1080 (i.e. above 1500 m above sea level), thereby excluding the majority of the target species from exposure.

Previous studies had also noted the importance of consistency throughout bait types (repellent and non-repellent), as kea are able to differentiate even small differences (Orr-Walker et al. 2012; Reardon 2014).

Previous captive repellent trials used undyed, plain cereal baits, which has the potential to make repellent baits look slightly different, as even well-blended anthraquinone has a reddish-brown hue (Reardon 2014). Once birds have experienced the effects of the repellent, in order to create and maintain a learned aversion, all subsequent baits must look and feel the same. Other primary cues such as taste and smell of a lure may also be important for maintaining aversion (Orr-Walker et al. 2012).

Bait Manufacture

We worked with Orillion Ltd (Wanganui, New Zealand) to manufacture four types of cereal bait, i.e. (i) standard W#7 lured with a double orange flavour, (ii) standard W#7 laced with 2.7% by weight anthraquinone [95% CI 2.6-2.9], (iii) standard RS5 lured with a double cinnamon flavour, and (iv) standard RS5 laced with 2.7% by weight anthraquinone.

These standard types of bait are representative of those in the 1080 to Zero prescription. All baits, both repellent and non-repellent, were dyed green and closely inspected for consistency in texture and colour. Sub-samples of all four bait types were assayed at Manaaki Whenua-Landcare Research (Lincoln, New Zealand), and physically inspected by the authors, for quality control and to confirm the above anthraquinone concentration.

Trial Design

These captive trials were conducted with approval from the Lincoln University Animal Ethics Committee (AEC 2018-44). Trials took place at the captive kea facility at Willowbank Wildlife Reserve (Christchurch). The trial involved 11 kea (one other bird was transferred to another facility partway through the W#7 sessions, and another bird at the facility was unable to consume any cereal baits due to a beak deformity).

Each trial 'session' ran over two consecutive days, with two days of normal diet between sessions. The specific dates and order of bait type used can be found in Table 1. The normal diet food was withheld from the birds until the conclusion of each day's bait exposure session.

Each session day consisted of a small group of feeding observers (teams of 4-5), plus two overseers (recording continuous behavioural data and monitoring bird health). Each trial session began at 08:00, and continued for up to 3½ hours. Each observer presented a single bait at a time, and recorded the interactions and/or feeding events that followed. Once a bait had either been consumed or discarded (into an irretrievable area of the enclosure), this process was repeated to ensure all birds had maximum opportunity to encounter and consume bait. Individual birds were deemed to have finished their feeding session by a halt in feeding of >15 minutes from last consumption, and were no longer presented with further baits.

Two overseers recorded continuous observations of behaviours and general activity levels for all individuals from the start till end of each session. This monitoring was highly important particularly during the repellent sessions, as some birds became unwell at various points in the session. We calculated the estimated LD50 for 1080 and kea (although no formal number exists) from studies on Australian parrots (Mcilroy 1984). LD50 is the amount of a toxic agent (in this case, 1080) that is sufficient to kill 50% of a population of animals (in this case, kea), usually within a certain time. As these are based on individual weight, we estimated the lower limit of LD50 at 0.35 of 1 cereal bait, and upper limit at 0.9 of a bait.

Observers and overseers wore ever-changing disguises between sessions, with the exception of consistent masks worn during non-repellent sessions (see Table 1). Disguises were considered necessary to remove any other 'cues' such as individual human faces and keep the birds' focus on bait alone. Observers were distributed around the enclosure in order to reduce competition for baits at any one location. In an effort to maximise exposure to all birds in the enclosure, observers moved around as necessary with individual birds.

Table 1. Trial session dates, bait type used, and observer & overseer disguise.

Session dates	Bait type	Observer & Overseer disguise
Session 1 November 11th-12th	W#7 non-repellent	Pink and white mask
Session 2 November 15th-16th	W#7 repellent	Green mask

Session 3 November 19th -20th	W#7 repellent	Blue and green mask, and orange high visibility jacket
Session 4 November 23rd -24th	W#7 non-repellent	Pink and white mask
Session 5 November 27th -28th	RS5 repellent	Balaclava/buff
Session 6 December 1st -2nd	RS5 repellent	Fox mask
Session 7 December 5th -6th	RS5 repellent	Assorted animal masks
Session 8 December 9th -10th	RS5 non-repellent	Pink and white mask

The order in which the different bait types were presented in the different sessions (i.e. W#7 before RS5) replicates that of the proposed 1080 to Zero operation. The local population of kea in the Perth River valley were exposed to standard (i.e. non-repellent and undyed) W#7 pre-feed during winter 2018. In order to better understand the implications of this prior exposure, we began this trial with standard W#7 (i.e. non-repellent) bait.

In order to sustain aversion in the Perth River valley kea population, ZIP proposes to expose kea to repellent baits prior to each application of 'standard' prefeed or toxic bait. To replicate this sequence, birds were not presented with standard (i.e. non-repellent) RS5 bait at the start of the sessions using that matrix.

Data Analysis

Bait consumption was the primary record taken throughout these trials. Numbers of baits consumed by individual birds were recorded and where part of a bait was consumed, it was categorised as follows: 0.13 (1/8), 0.25 (1/4), 0.50 (1/2), 0.75 (3/4) or 1 of a whole bait.

RESULTS

Baseline consumption (as taken from session 1 W#7) of non-repellent bait showed 10 out of the 11 captive birds readily consumed bait.

Birds continued to consume bait on days 1 and 2 of session 2; however, the consumption rate began diminishing by the end of day 2, as most individuals were experiencing negative effects from the repellent bait over time (Fig. 1). Behaviours associated with the repellent effects included fluffed feathers, gripping stomach with feet, gaping/head shaking, beak wiping, gagging, and inactivity.

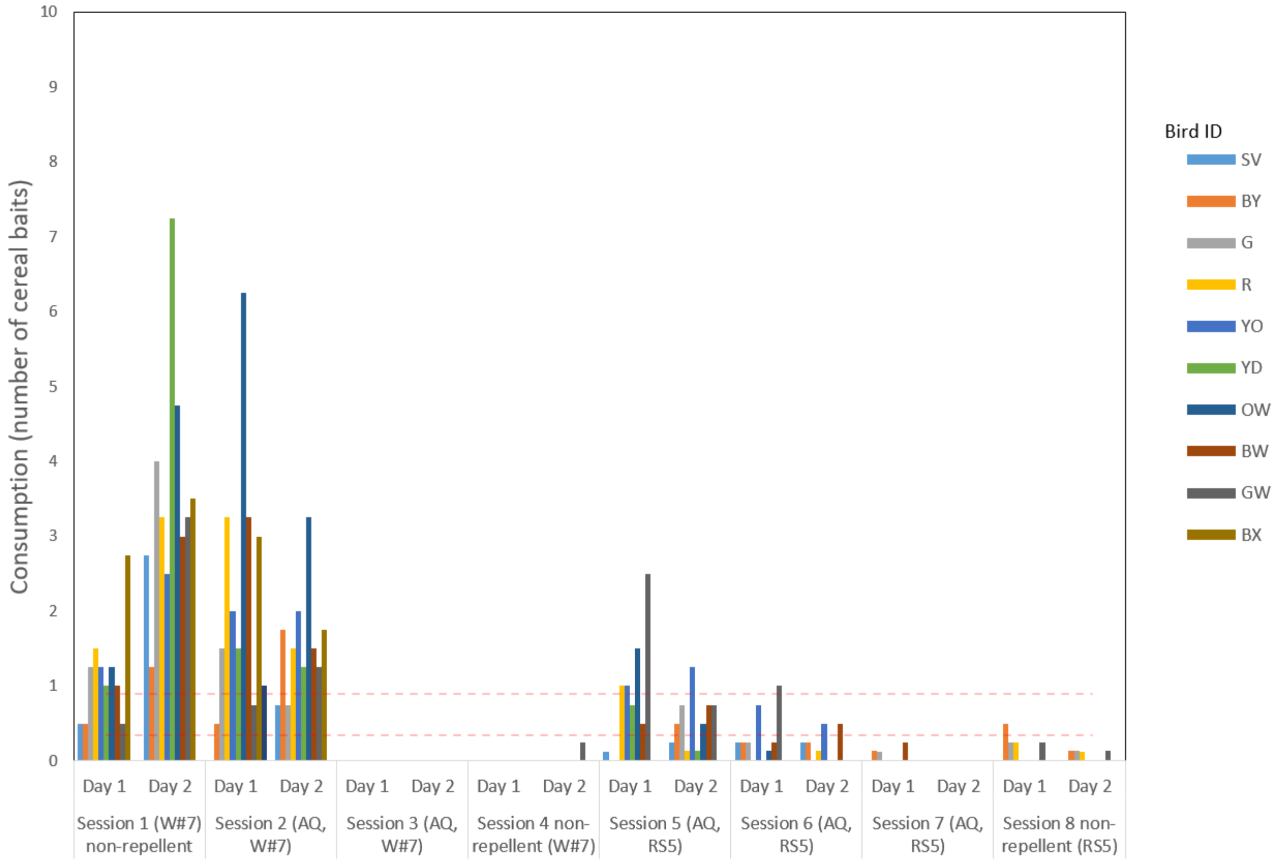
No birds consumed bait in session 3, and only one bird consumed a portion of a bait (0.25 of a bait) during day 2 of session 4 (non-repellent test for W#7 bait type).

There was a notable increase in consumption in session 5 when the RS5 bait type was introduced; however, this again diminished as the sessions went on and the birds showed symptoms of the repellent post-consumption (Fig.1).

Only one bird consumed sufficient bait (0.5 of a bait) over the entire feeding exposure period of day 1 of session 8 (non-repellent test for RS5 bait) to be within the LD50 range. Three other birds consumed 0.25 of a bait each in that same session. By day 2 of session 8, none of those same four birds consumed sufficient bait to be within the LD50 range (all consumed 0.13 of a bait).

Figure 1 also shows the estimated LD50 for comparably-sized parrots (Mcilroy 1984), as this is the relevant comparison measure.

Figure 1. Number of cereal baits consumed per bird, per session, and the estimated LD50 limits of 1080 for kea.



DISCUSSION

This study showed that repeated exposures of captive kea to non-toxic prefeed cereal baits laced with a concentration of 2.7% anthraquinone by weight reduces consumption of standard bait (i.e. not laced with anthraquinone) upon subsequent presentation, through a conditioned learned aversion.

Working in an aviary setting where there is sufficient space for birds to fly out of an individual observer's field of view has its challenges. In addition, there is a definite hierarchy among the captive birds, and some individuals would regularly steal baits from other birds. However, using a large team of observers and additional overseers helped to negate any issue of not seeing what the birds were doing at any one time. We are confident that, as a team, we were able to identify all bait interaction and consumption activity, as well as record subsequent repellent effect post-ingestion.

One of the critical factors in the successful reduction in consumption was manufacturing consistency in bait quality across all bait types. The two bait matrices, W#7 and RS5, are inherently different in their texture. However, the colour consistency (green) across both types and within bait types (repellent and non-repellent) was the same.

The increase in consumption with RS5 confirmed that birds were not only taking cues from the visual nature of the baits (consistently green), but also the taste and smell of the added lure. Observers often noted birds holding baits with their feet and intensively sniffing them before tasting, and then deciding whether to consume or discard. As such, we believe the lures used for each bait type (orange for W#7 and cinnamon for RS5) acted as a primary cue for birds. The birds appeared to detect the orange lure when presented with repeated W#7 bait, and they would use this as a cue to avoid subsequent bait offers based on a generalised learned aversion to baits of the same visual and textural nature, as well as taste and smell. Although consumption did not decline as rapidly during the RS5 sessions, this appeared to be from a heightened degree of hesitation among the birds to bait in general; and thus, many individuals were slow to consume enough bait to feel the repellent effects.

We are currently working with Callaghan Innovation to better understand the potential ultraviolet (UV) signature of anthraquinone, and how this may be interpreted by birds when encountering cereal bait. However, results of these current repellent trials suggest the appearance of the bait (perhaps attributable to the green dye across all bait types) was sufficient to mask the UV signature of the added anthraquinone, if it is indeed present at all.

The success of these repellent trials gives us a tool to potentially mitigate kea risk, by training conditioned aversion into wild population. The design for implementation of anthraquinone repellent cereal bait as part of the proposed Perth Valley operation is now underway.

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Lynn Booth (Maanaki Whenua-Landcare Research) undertook our assays as we sought to understand what concentration was best suited to this trial. John Quigley, Craig Lewis and Donna Hall from Orillion laboured over getting the anthraquinone concentrations right, the bait appearance consistency even, and the green colour accurate through all baits.

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REFERENCES

Bell P 2017. 1080 to Zero: Jackson-Arawhata. Technical report #1. Zero Invasive Predators. Wellington. http://zip.org.nz/findings/2017/11/1080-to-zero-trial-in-south-westland

Bell P, Nathan, H., Mulgan, N 2019. 'Island' eradication within large landscapes: the remove and protect model'. *In*: C.R. Veitch, M.N. Clout, A.R. Martin, J.C. Russell and C.J. West (eds.) Island Invasives: Scaling Up to Meet the Challenge, pp. 600–606. Gland, Switzerland: IUCN.

Clapperton BK, Morgan DK, Day TD, Oates KE, Beath AM, Cox NR, Matthews LR 2014. Efficacy of bird repellents at deterring North Island robins (Petroica australis longipes) and tomtits (P. macrocephala toitoi) from baits. New Zealand Journal of Ecology: 116-123.

Cowan P, Booth L, Crowell M 2016. Repellents with potential to protect kea and other native birds from aerial poisoning for possum and rat control. New Zealand Journal of Ecology 40(1): 1.

Cowan P, Brown S, Forrester G, Booth L, Crowell M 2015. Bird-repellent effects on bait efficacy for control of invasive mammal pests. Pest management science 71(8): 1075-1081.

Crowell M, Martini M, Moltchanova E 2016. Effect of the addition of bird repellents to aerially applied 1080 baits on rat and possum abundance. New Zealand Journal of Ecology 40(1): 49-59.

Eason C, Miller A, Ogilvie S, Fairweather A 2011. An updated review of the toxicology and ecotoxicology of sodium fluoroacetate (1080) in relation to its use as a pest control tool in New Zealand. New Zealand Journal of Ecology: 1-20.

Greer AL, Gajdon GK, Nelson XJ 2015. Intraspecific variation in the foraging ecology of kea, the world's only mountain-and rainforest-dwelling parrot. New Zealand Journal of Ecology 39(2): 254-261.

Kemp JR, Mosen CC, Elliott GP, Hunter CM 2018. Effects of the aerial application of 1080 to control pest mammals on kea reproductive success. New Zealand Journal of Ecology 42(2): 158-168.

Kemp JR, Mosen CC, Elliott GP, Hunter CM, van Klink P 2019. Kea survival during aerial poisoning for rat and possum control. New Zealand Journal of Ecology 43(1): 0-0.

Mcilroy J 1984. The Sensitivity of Australian Animals to 1080 Poison. Vii. Native and Introduced Birds. Wildlife Research 11(2): 373-385.

Orr-Walker T, Roberts L 2009. Population estimations of wild Kea (Nestor notabilis). Kea Conservation Trust.

Orr-Walker T, Kemp J, Adams NJ, Roberts L 2015. A strategic plan for kea conservation. A collaboration between the Department of Conservation (DOC) and the Kea Conservation Trust (KCT).

Orr-Walker T, Adams NJ, Roberts LG, Kemp JR, Spurr EB 2012. Effectiveness of the bird repellents anthraquinone and d-pulegone on an endemic New Zealand parrot, the kea (Nestor notabilis). Applied Animal Behaviour Science 137(1): 80-85.

Reardon J 2014. Kea repellent development report July 2014. Unpublished report to Department of Conservation, 20 p. .

Van Klink P, Crowell MD 2015. Kea (Nestor notabilis) survivorship through a 1080 operation using cereal baits containing the bird repellent d-pulegone at Otira, central Westland, Publishing Team, Department of Conservation.

Werner SJ, Linz GM, Carlson JC, Pettit SE, Tupper SK, Santer MM 2011. Anthraquinone-based bird repellent for sunflower crops. Applied Animal Behaviour Science 129(2): 162-169.