

VISUAL DISCERNMENT BY KEA OF DIFFERENT CEREAL BAIT TYPES; USING A VISUAL MODEL BASED ON PARROTS.

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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 predator 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 parrot that is endemic to the South Island of New Zealand (Orr-Walker et al., 2015; Van Klink and 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 and 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 currently implementing a modified aerial 1080 prescription known as '1080 to Zero' (Bell, 2017) at an approx. 10,000 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 Perth River valley site holds an estimated population of 75-100 kea (I. Graham, DOC, pers. comm. 2018).

The current 1080 to Zero operation was previously intended for 2018; however, severe and prolonged inclement weather forced the operation to be postponed until present-time, 2019. During the second pre-feed phase of the intended 2018 operation, ZIP aimed to assess

the relative risk to kea using cereal bait (undyed, Wanganui #7, orange lured), laced with a non-toxic biomarker, pyranine. Pyranine produces a fluorescent bright green colour which reflects in the UV spectrum. A small sample of kea were able to be captured post-pyranine pre-feed (n= 11) and examined under UV light for signs of consumption or interaction with cereal bait (ZIP, 2018). Although there was a higher than expected interaction rate with the pyranine-laced cereal baits, there was uncertainty as to whether the birds were able to see the fluorescent green colour, which may have had an influence on interaction rates.

One strategy for potentially reducing consumption of toxic cereal bait by wild kea is creating and maintaining a conditioned aversion to cereal baits that mimic the visual, textural, and olfactory nature of 1080 baits (i.e. green dyed, and lured with either orange or cinnamon), in two standard bait types, Wanganui #7 and RS5; (Nichols and Bell, 2019a; b), through the addition of a secondary bird repellent, anthraquinone (e.g. Cowan et al. 2016). A detailed explanation for operational implementation of this strategy can be found in Nichols & Bell (2019b).

Anthraquinone is a widely used secondary repellent for birds (Werner et al., 2011; Orr-Walker et al., 2012; Cowan et al., 2016). Unlike a primary repellent (a chemical that birds avoid due to irritation of their peripheral senses (Sayre and Clark, 2001)), a secondary repellent acts through gastrointestinal irritation (i.e. causing gagging and vomiting), to create a learned aversion to that substance (Orr-Walker et al., 2012; Nichols and Bell, 2019b).

Captive ship rats are known to develop an aversion to anthraquinone treated baits at both 0.1% and 0.25% (Cowan et al., 2015). Anthraquinone at those concentrations also reduced palatability in captive possums, but not enough to reduce the efficacy of toxic baits (Cowan et al., 2015). The risk of target species developing a learned aversion to anthraquinone requires operational implementation of aversion training to occur at locations where the operational target species (i.e. rats and possums) are not able to access it (i.e. at altitudes where kea are present but those other species are not, such as above the elevational treatment boundary at a site).

Kea are highly perceptive to novelty (Greenberg, 2003), thus it is important to ensure that anything added to the bait does not generate a behavioural response resulting in increased interaction (and potentially consumption), e.g. if the operational bait looks different to the repellent bait. Weser and Ross (2013) found strong colour preferences in captive kea. Such colour preferences were surprising given kea are opportunistic foragers with a diverse environment (Young et al., 2012); and seemingly have no, or very little neophobic response towards novel food (Huber and Gajdon, 2006; Weser and Ross, 2013).

Because birds can see in UV, anthraquinone, which reflects in the UV spectrum, is thought to be visible to them (Du et al., 1998; Orr-Walker et al., 2012), thereby potentially risking the effectiveness of the learned aversion once bait is presented without the anthraquinone present.

As there are no measured relative photo-receptor densities available for kea, visual models were constructed using mean absorbance spectra of the parrot *Platyercus elegans* (Crimson rosella) (Knott et al., 2013), and relative photoreceptor densities of the parrot *Platyercus eximus* (Eastern rosella) (Hart, 2001), both Australian species. We tested whether the vision of these parrots (extrapolating to kea as they are also a species of parrot) can visually discern between several different non-toxic cereal baits. We compared these different cereal baits, some containing anthraquinone (repellent) or pyranine (biomarker), as well as plain/undyed, using colour analysis that incorporates the bird's vision. In parrots, the retinae contain four classes of single cones, each containing a different visual pigment: longwave-sensitive (LWS), medium-wavelength-sensitive (MWS), short-wavelength-sensitive (SWS) and ultraviolet-sensitive (UVS). This is different to human vision, which only contain three classes.

OBJECTIVE

We aim to examine and compare the significance, or lack thereof, for visual differences between types and colours of cereal baits, in terms of a kea's vision. However, the comparative attractiveness of different types and colours to kea, as well as additional olfactory cues added to cereal baits, is beyond the scope of this study.

TRIAL DESIGN/METHODS

Bait Manufacture

We worked with Orillion Ltd (Wanganui, New Zealand) to manufacture all cereal bait types used in the study (Table 1).

The standard bait matrices used in his study (Wanganui #7 and RS5) are representative of those used in standard aerial 1080 operations (Brown et al., 2015), and the 1080 to Zero prescription. Samples of each bait type were closely inspected for consistency in texture and colour. Samples of all bait types were assayed at Manaaki Whenua-Landcare Research (Lincoln, New Zealand) for quality control and to confirm the intended anthraquinone concentration.

Trial Design

Spectral measurements of 10 different types of bait (listed in table 1) were measured using a fibre optics spectrometer, with a diffuse white reflectance standard as a reference for white light. We used a sample size of 12 different baits for each bait type.

Mean reflectance values from 300 to 700nm were calculated for each bait type. To determine whether kea can tell the difference between any two baits, PAVO in R (Maia et al. 2013) – utilizing the 'receptor-noise' model (Vorobyev & Osorio, 1998) – was used to model their visual system. Any differences between mean reflectance of two baits are given as Just Noticeable Differences (JNDs) and values <1 indicate no detectable colour difference for the bird.

Table 1: Description of each bait type; with labels used in the model

Label in model	Description
WG00	Wanganui # 7 cereal bait, dyed green with 0% anthraquinone, and orange lured
WG01	Wanganui # 7 cereal bait, dyed green with 2.8% anthraquinone, and orange lured
WG02	Wanganui # 7 cereal bait, dyed green with 3% anthraquinone, and orange lured
WG03	Wanganui # 7 cereal bait, dyed green with 3.1% anthraquinone and orange lured
WG04	Wanganui # 7 cereal bait, dyed green with 3.2% anthraquinone and orange lure
WNL1	Wanganui # 7 cereal bait, undyed, with 2.9% anthraquinone and <u>no</u> lure
WND1	Wanganui # 7 cereal bait, undyed, with 2.8% anthraquinone and orange lure
RS00	RS5 cereal bait, dyed green with 0% anthraquinone and cinnamon lured
RS01	RS5 cereal bait, dyed green with 2.7% anthraquinone and cinnamon lured
WNP1	Wanganui # 7 cereal bait (undyed), laced with <u>0.2%</u> pyranine, and orange lured

To do this, we constructed a visual model based on mean absorbance spectra of *P. elegans* (Knott et al., 2013) and relative photoreceptor densities of *P. eximus* (Hart, 2001). There are no measured relative data for kea; so these data were used to extrapolate to kea (acknowledging they are a parrot, albeit from a different geographical region). The ability for kea to view certain colours against different backgrounds (i.e. tussock, rock, leaves, grass, dirt) was accounted for using Von Kries colour corrections.

RESULTS

Our model suggests that parrots (therefore likely kea) are unable to detect visual differences between cereal baits of the same colour (dyed green vs dyed green; or undyed vs undyed) – even when comparing cereal baits treated with repellent vs. non-repellent. However, parrot vision is able to discern between plain, undyed cereal baits (WNL1 and WND1) and undyed cereal baits laced with pyranine (WNP1); which suggests the UV reflectance of pyranine is highly visible to kea.

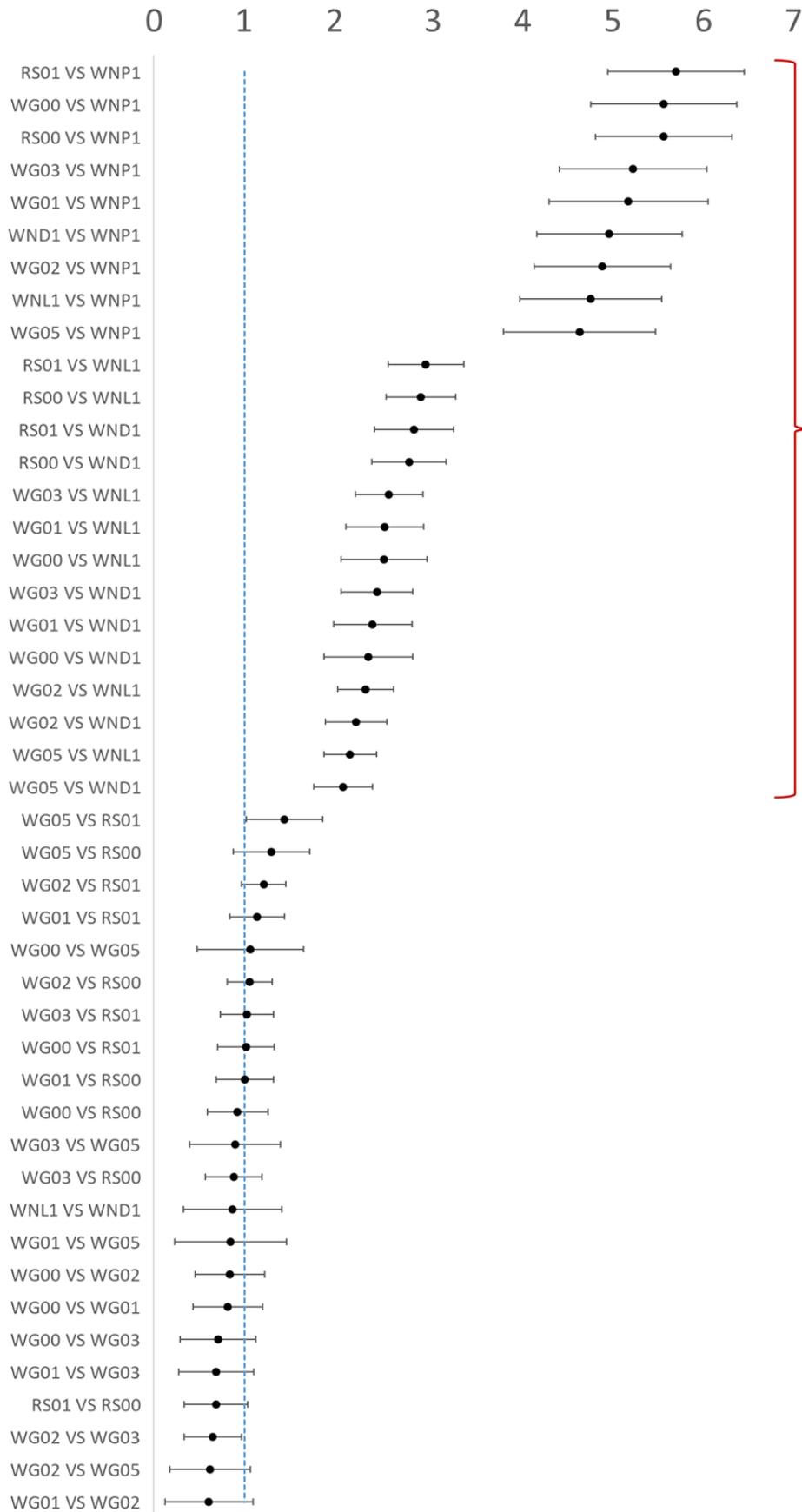
Based on the parrot visual model, kea could be expected to detect a difference between baits whenever green-dyed bait was compared against undyed bait.

Based on the Von Kries colour corrections, background was not found to affect discernibility.

The results of all bait comparisons for visual discernment are presented in Figure 1.

JND ± standard error

> 1 is a detectable difference



DISCUSSION

To our knowledge, this study is the first to measure visual perception of different cereal baits by parrots. In this study, we do not address behavioural preferences for different cereal baits, nor the olfactory component of lures added to cereal baits used in standard operations; all of which may influence interaction rates between wild kea and cereal baits. Model results are based strictly on the perspective of a parrot's vision. Thus, we assume throughout this study that these results may be extrapolated to kea (acknowledging they are an endemic to NZ, while the model is based on data from Australian parrots).

Overall, these results support the assumption that kea can discern between baits of different colours (e.g. green dyed versus plain (light brown) bait). Standard 1080 aerial operations use undyed non-toxic cereal bait, followed by green-dyed toxic cereal bait. Kea are known to investigate novel food objects, and often forage on the forest floor where cereal baits may be found during operations in kea habitat. There is a possibility that the change of bait colour could create a novelty effect which may increase interaction rates with bait by kea. We thus highlight the importance of considering the appearance of these baits from a kea's perspective.

In 2018, ZIP found that wild kea in the Perth River valley exhibited a higher than expected interaction rate with non-toxic cereal bait laced with a biomarker, pyranine (ZIP, 2018). In the present study, we find that parrots can detect a visual difference between plain, undyed cereal bait (WNL1 & WND1) and cereal bait laced with pyranine (WNP1). Humans are unable to discern the visual difference in these baits (unless the cereal bait laced with pyranine is viewed under UV light). We may be unable to identify what drove the small sample of wild kea to interact with the cereal bait laced with pyranine. However, we can conclude that these cereal baits would have appeared visually different to the plain cereal baits they had previously been exposed to.

We have determined that parrots, and presumably kea, are unlikely to be able to tell the difference between green-dyed cereal bait (no repellent), and green-dyed cereal bait treated with anthraquinone (repellent). Anthraquinone is frequently used as a repellent for birds, and we have previously found that it can successfully reduce the consumption of cereal baits by kea (Nichols and Bell, 2019a) through a conditioned aversion. This inability of the birds to visually discern between cereal baits treated with anthraquinone and untreated cereal bait when dyed a consistent green colour – supported by the results of Nichols and Bell (2019b) – is valuable knowledge for future aversion training.

This study demonstrates that future conservation practices should consider how birds, rather than humans, perceive colours – particularly when dealing with species that are innately curious. This may become more important as conservation efforts intensify with Predator Free New Zealand (Russell et al., 2015), and an increasing number of predator removal operations occur across the habitats of potentially vulnerable non-target bird species.

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