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RESEARCH

Using para-aminopropiophenone (PAPP) as a tool to control feral cats in Hawke's Bay, New Zealand

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Abstract: The impact of feral cats on native wildlife is becoming increasingly recognised worldwide, making their management a necessity. As New Zealand's Predator Free 2050 goal leads to larger and more ambitious landscape scale programmes, there is an important need for cost- and time-effective tools. Para-aminopropiophenone (PAPP) was first registered in New Zealand for feral cats and stoats in 2011 under the name PredaSTOP® and has higher target specificity for feral cats than currently used toxins. Following a successful trial of PAPP on Toronui Station, Hawke's Bay in 2017, a larger operation was undertaken in 2018 across 9123 ha of the Poutiri Ao ō Tāne project area in Hawke's Bay. Camera traps were used to monitor the relative abundance of feral cats on Opouahi Station (treatment site) and at Waitere Station(non-treatment site). A network of 287 bait stations was established in 500 m grid spacings across the treatment site. Two applications of non-toxic pre-feed minced meat baits were followed by two applications of toxic PAPP baits. PAPP baits were dyed green and contained 80 mg of PredaSTOP® in the centre of the bait. Each application of PredaSTOP® consisted of two baits placed at either end of each bait station. Toxic baits were removed from at least 130 bait stations. We assume that ≥ 130 feral cats are likely to have been killed, resulting in a 39% reduction in the relative abundance of feral cats after the operation. Our results suggest that PAPP has the potential to be a useful management tool across large areas alongside other methods.

Keywords: camera traps, feral cat, *Felis catus*, invasive species, PAPP, PredaSTOP®

Introduction

The impact of feral cats (*Felis catus*) on native wildlife is becoming increasingly recognised worldwide, making their management a necessity (Campbell et al. 2011; Doherty et al. 2016; Rouco et al. 2017). Feral cats are a significant predator in non-bush habitats and are notoriously difficult to manage, particularly across large areas. Feral cats on Hawke's Bay farmland have been recorded eating native birds as well as invasive species (Langham 1990) and are also a definitive host of toxoplasmosis, which is harmful to livestock and wildlife (Buxton et al. 2007; Roberts et al. 2019). The Parliamentary Commissioner for the Environment has identified "the urgent need to tackle the problem of feral cats effectively and humanely" and urged development and trial of new tools and techniques (PCE 2017). As New Zealand's Predator Free 2050 goal results in larger and more ambitious mainland landscape-scale predator control projects, effective and varied tools are of greater importance.

Landscape scale cat control is predominantly undertaken using live capture and kill traps despite the fact that poison baiting is more cost-effective (Fisher et al. 2015). Additionally, all successful island cat eradication campaigns, except two, have used poisoning as the primary control method (Campbell et al. 2011). However, poison baiting for feral cats has had little use on mainland New Zealand, primarily due to lack of effective and humane baits, risks to non-target individuals (e.g. domestic cats and dogs), and restrictions on use. Additionally, there is little research on the impact of feral cats on native fauna to support targeted control operations, the population impacts from large-scale control, and the rapidity of reinvasion.

Para-aminopropiophenone (PAPP) was registered for feral cat and stoat (*Mustela erminea*) control in New Zealand in 2011 under the trade name PredaSTOP® and has had limited use for feral cat control, partly due to notification requirements specifying all owners and householders within 3 km of a treatment area be notified (D MacMorran – CEO Connovation Ltd, pers. comm.). PAPP works by limiting oxygen to cardiac muscle and the brain, creating a fatal deficit within two hours of a dose (Eason et al. 2014). Clinical symptoms (lethargy and sleepiness) start around 35 minutes after ingestion, and PAPP is therefore considered humane (Eason et al. 2014). PAPP has higher target specificity than currently used toxins for feral cats and has a readily available, effective antidote in the form of Methylene blue (Fisher et al. 2015). Best practice specifies baits are deployed for five to seven days to retain palatability (Shapiro, 2018).

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The Poutiri Ao ō Tāne project began in 2011 as a proof of concept for large-scale, low-cost predator control across farmland, and to quantify how this type of programme can benefit farming operations, biodiversity and adjacent conservation areas. Feral cats were initially controlled across 6000 ha by a combination of shooting and live-trapping (Glen et al. 2019). In 2017 predator control was extended to include an additional property, Toronui Station (1000 ha).

PAPP baits were trialled as a tool for rapid knock down of the feral cat population on Toronui Station. Camera monitoring showed a 50% reduction in relative abundance of feral cats after a single toxic bait application (Glen et al. 2017). However, anecdotal evidence from farmers indicated that this area was rapidly recolonised within a few months by feral cats from adjacent areas. A similar operation during 2017 on neighbouring Ngatapa Station achieved a 73.5% reduction in feral cat detections using the same operational protocol, but with two applications of PAPP instead of one (Shapiro 2018). The short-term success of these trials, and difficulties in reducing feral cat densities using live capture trapping in Poutiri Ao ō Tāne, led to a further application of PAPP across the entire Poutiri Ao ō Tāne project area in 2018.

Targeted feral cat control in Poutiri Ao ō Tāne and Cape to City (sister project) has predominantly consisted of live capture trapping using cages and leghold traps. Understanding the time, cost and catch rate differences between live capture trapping and PAPP will be important in future management decisions. The aims of this study were to: 1) estimate the relative abundance of feral cats before and after a PAPP baiting operation, and 2) compare the efficacy and cost-effectiveness of PAPP to other feral cat control methods.

Methods

Study area

The treatment area covered 9123 ha of the Poutiri Ao ō Tāne project in Northern Hawke's Bay across five neighbouring properties including Toronui, Opouahi, Rangiora and Mataterangi Stations, and the Department of Conservation's (DOC) Boundary Stream Mainland Island and Bellbird Bush (39º10′ S, 176º46′ E). All these properties connect to form a continuous operational area. The pastoral stations (c. 8200 ha) were a mix of pasture, rocky outcrops and fragments of native beech forest (*Fuscospora solandri*), and mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea ericoides*) scrub. Boundary Stream is predominantly forested with tawa (*Beilschmiedia tawa*), tītoki (*Alectryon excelsus*) and rewarewa (*Knightia excelsa*) while Bellbird Bush is dominated by red beech (*Nothofagus fusca*) and black beech (*Fuscospora solandri*) in the northern area and mānuka scrub in the southern.

The operational area ranges from 300 to 900 m above sea level and average temperature ranges from 6.5°C in winter to 16.5°C in summer. Annual rainfall averages c. 1500 mm and while winter is the wettest season, rainfall is reasonably evenly distributed throughout the year. Winter 2018 experienced normal temperatures and rainfall; however, rainfall was unevenly distributed with June receiving double the average, July half the average and August close to average.

Camera monitoring

Camera traps were used to monitor the relative abundance of feral cats on Opouahi Station and at a non-treatment site (Waitere Station > 4.3 km from the treatment area north of Maungaharuru range). Grids consisted of 40 cameras (Browning Strike Force BTC-5, Prometheus Group, Birmingham, Alabama) at 500 m spacings, and were deployed for three weeks before pre-feeding (see below), and for three weeks after toxic baits had been removed. Cameras were mounted on a post or tree 10 cm above the ground facing south to avoid being triggered by the sun. A scent lure (ferret body odour; Garvey et al. 2017) contained in a plastic vial was pegged 1.5 m in front of the camera (Glen et al. 2017). All cameras were programmed to take a burst of three images in quick succession each time the sensor was triggered. Cameras were located as closely as possible to grid locations randomly pre-selected on ArcGIS.

An additional eight cameras were deployed at bait stations where pre-feed had been taken during the period of the 14 day poison baiting period. These eight cameras followed the same protocol as the camera monitoring grids. Cameras were programmed to take a burst of three images in quick succession each time the sensor was triggered, and were mounted 10 cm above the ground, facing the bait station from a distance of 1.5 m. The purpose was to gain information on bait take, non-target interactions and feral cat behaviour.

Poison baitings

Poison baits consisted of 15 g minced rabbit or beef meat rolled into a ball with 200 mg of predaSTOP® paste (Connovation Ltd, Auckland) in the centre. Toxic baits were dyed green to distinguish from non-toxic baits, as a legal requirement of use.

The Best Practice Guidelines (Shapiro 2018) specify both rabbit and beef mince can be used for making PAPP baits for feral cat control, however the small number of trials undertaken in New Zealand have favoured using rabbit and any feral cat preferences are currently unknown.

The 287 bait stations were established in 500 m grid spacings across the treatment area. To prevent access by non-target animals, "chimney" style bait stations were used (Fig. 1). These wooden bait stations have mesh at either end and an opening at the top, and have been used in both trapping operations and in successful feral cat PAPP operations (Shapiro 2018).

Two non-toxic pre-feed baits (one rabbit, one beef mince) were placed in each bait station at either end, with placement decided randomly. These 15 g non-toxic baits were refreshed after 7 days and left in place for a further 7 days before being replaced with poison baits. Poison baits were deployed in the same manner as non-toxic pre-feed, two baits per station in the same placement as non-toxic. Two rounds of toxic baiting were undertaken with baits replaced at 7 day intervals, ensuring continuous baiting over the total four week period. At the conclusion of the baiting period all remaining baits were removed from bait stations.

Reducing risk to domestic cats and non-target species

Risk to domestic cats was minimised through providing the opportunity for all landowners to house any domestic cats in a cattery for the duration of the operation. Chimney bait stations have been effective at minimising non target species accessing bait due to the vertical entrance shaft.

Statistical analysis

As specified by Garvey et al. (2017) if photographs occurred within 30 minutes a single encounter was assumed unless individuals were clearly different (e.g. based on coat colour).

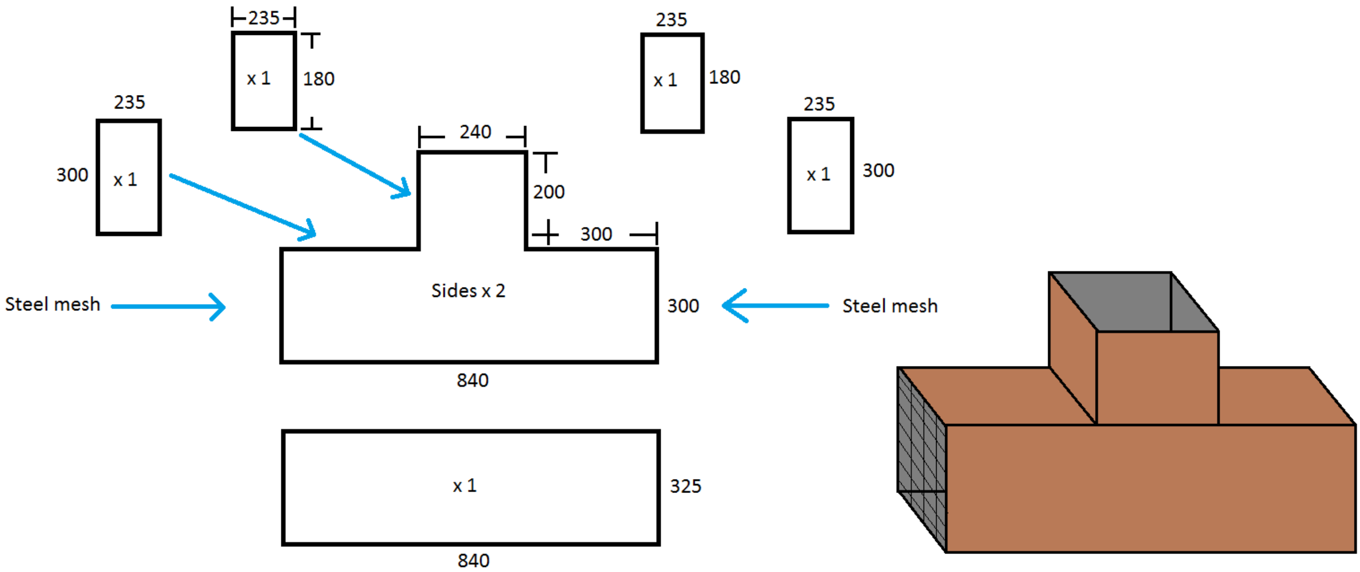

Figure 1. Diagram of the 'chimney' style bait station used to allow access by cats while excluding non-target species (from Shapiro 2018).

Images were processed manually and the results entered into a spreadsheet. The relative abundance of feral cats pre- and post-treatment was estimated using camera trap rate (CTR), calculated as the number of independent photographs per 100 camera trap days (Rovero & Marshall 2009). CTR does not account for imperfect detection.

To determine whether differences in CTR between the pre- and post-treatment periods were statistically significant, we calculated the rate ratio and associated 95% confidence interval (CI) (Kirkwood & Sterne 1988). If the rate ratio is less than one and the 95% CI does not overlap one this indicates a statistically significant decrease in CTR after baiting.

Comparison to live capture

To determine how cost- and time-effective PAPP is compared to live capture using leghold traps and cages, we compared hours spent and number of cats removed to two large live capture feral cat control programmes: Cape to City Area A (2016), and the Poutiri Ao ō Tāne extension (2019) (Hawkes Bay Regional Council, unpubl. data). Both operations used live capture cages and legholds deployed at one per 20–40 ha spacings for 10 nights. Two field staff deployed traps across a c. 2000 ha block. After 10 nights traps were moved to the next block to form a "rolling front" until the whole area had received control.

Results

Before PAPP was applied to the treatment area, camera monitoring detected cats on 56 occasions at 24 cameras resulting in a CTR of 6.7% (95% CI 5.1–8.6%). During the post-treatment period, cats were detected on 34 occasions at 16 cameras, CTR 4.1% (95% CI 2.8–5.6%). The relative abundance of cats is therefore estimated to have been reduced by 39%. The rate ratio of CTR before and after PredaSTOP® baiting was 0.6. The 95% confidence interval for the rate ratio (0.4–0.9) did not overlap one, indicating that the difference was statistically significant.

At the non-treatment site, cats were detected on 16 occasions at 12 cameras during the pre-treatment period (CTR 1.9%; 95% CI 1.1–3.1%). In the post-treatment period cats were detected on 12 occasions at nine cameras (CTR 1.4%; 95% CI 0.7–2.5%). The rate ratio of CTR between the pre-and post-treatment periods was therefore 0.75. However, the 95% CI (0.4–1.6) overlaps one, indicating no significant difference.

The eight camera traps placed on bait stations showed feral cats readily accessing the stations. One camera recorded two different individuals taking bait, distinguishable by coat colour. Other species such as hedgehogs, pheasants and livestock showed interest in the stations, but did not access them. No stoats or ferrets were detected.

Of the 287 bait stations that bait was placed in, during the first toxin pulse, 145 baits were taken from 85 bait stations (excluding 53 stations on Toronui where data collected were lost), and during the second pulse, 65 baits were taken from 45 bait stations (Table 1).

Data collection on rabbit or beef bait take was not consistent, precluding formal analysis. However, of all bait take (including prefeed), 503 bait stations had both baits removed and 509 had no baits taken. Of the 52 stations where only one bait was removed, 32 had rabbit taken, six had beef mince taken and 14 were not recorded. Two stations had half of each bait removed. These results suggest that rabbit meat may be preferable as a medium for bait, but more robust data are required.

Across the farmland area managed by Hawke's Bay Regional Council (HBRC), the PAPP operation took 56 person days, while Boundary Stream and Bellbird Bush required 22.5 person days.

Of the four domestic cats resident within the operational area, one was housed for the duration of the operation in a cattery and one bait station was unfilled due to the vicinity to the dwelling. No domestic cats from inside the operating area or on neighbouring properties were reported missing. Apart from one dead mouse inside a bait station, there was no evidence of non-target consumption of baits.

Table 1. Summary of bait take

Operation Area	Total bait stations	Toxin 1	Toxin 2	Field Days to refill	Minimum cats assumed removed
Boundary Stream/ Bellbird Bush (DOC)	53	31 baits/20 stations	21 baits/13 stations	4.5	33
HBRC	234	114 baits/65 stations*	44 baits/32 stations	8	92

*data was lost from 53 bait stations therefore 181 total bait stations

Discussion

Given that toxic baits were removed from at least 130 bait stations, we assume that ≥ 130 feral cats are likely to have been killed, resulting in a 39% reduction in the detection of feral cats after the operation. We assumed that, due to rapid onset of symptoms following ingestion of a fatal dose, cats were unlikely to remove bait from more than one bait station. If both baits were removed from a station, we assumed it was the same individual. However, camera monitoring showed baits in the same station can be consumed by different individuals. Thus, our estimated number of individuals killed may be conservative.

This reduction in feral cat detections and potential number of kills was achieved at less effort and cost than conventional techniques such as live capture. As a direct comparison, if we consider only the treatment area managed by HBRC, an equivalent live capture operation would require a rolling front of leghold and cage traps to be deployed for 10 trap nights and checked daily before being redeployed to the next area. Approximately 1000 ha can be checked by one staff member daily (depending on terrain and weather conditions), which equates to 80 person days for the 8000 ha area (HBRC, unpubl. data). Conversely, the PAPP operation required 56 person days over the same area.

If we also compare total kills to equivalent live capture operations, assuming 130 cats were killed by across 9123 ha, gives an average of one cat removed per 70 ha. Targeted feral cat control using leghold and cage traps was undertaken across Cape to City Area A (5829 ha) between April and June 2016. This operation took 60 field days and resulted in 72 cats killed (an average of one cat removed per 81 ha) (Glen 2016). A similar operation to extend Poutiri Ao ō Tāne down to Lake Tutira in 2019 (4000 ha) took 40 field days and removed 43 cats (one cat 93 ha^{-1}) (HBRC, unpubl. data). This means that on a per hectare basis, across farmland PAPP removed more cats than previous targeted trapping.

It is assumed that a minimum of 33 cats were killed in Boundary Stream and Bellbird Bush. This is the equivalent to annual trap catch rate for the reserves which averaged 32.5 cats annually since 2011 (DOC, unpubl. data). For the PAPP operation, each refill of bait stations in the reserves took 4.5 man days totalling 22.5 days.

Although statistically significant, the 39% reduction in CTR after two pulses of toxic bait is lower than expected given previous results from trials at Toronui and Ngatapa, and the high amount of bait take. In 2017 Toronui recorded a 50% reduction with only one toxin round (baits removed from 17 of 48 stations; Glen et al. 2017) and Ngatapa a 74% reduction with two toxic pulses (Boffa Miskell 2018). Both Toronui and Ngatapa were using PAPP as an initial knockdown tool with both areas having no recent history of feral cat control.

Feral cat home ranges can be very large and vary widely: a study of five feral cats GPS collared in New Zealand braided river valleys varied from 178 to 2486 ha (Recio et al. 2010). It is possible that any cats remaining post treatment increased their activity and/or home range after control due to reduced competitive behaviour and availability of females (Recio et al. 2010; Brook et al. 2012). Additionally, immigration by individuals from surrounding areas could mean only short-term reductions in the population (Bengsen et al. 2012).

A potential factor influencing the results from this operation is the impact of increased rabbit numbers in the treatment area. In Australasia the abundance of predators is usually driven by rabbit abundance (Cruz et al. 2013; Norbury & Jones 2015). Anecdotal evidence and night count monitoring from Opouahi and Rangiora Stations in autumn 2017 (6.6–11.3 rabbits km^{-1}) and 2019 (20.0–26.8) (HBRC, unpubl. data) showed a higher than average population of rabbits. This increased abundance of rabbits could mean that food was plentiful, leading to decreased uptake of baits. A radio tracking study on Ngamatea in June 2009 showed all 21 tracked cats fed regularly on bait in chimney bait stations (Murphy et al. 2011). However, rabbit night count monitoring on Ngamatea in 2009 showed low rabbit abundance at 0.6 rabbits km^{-1} (HBRC, unpubl. data).

Results from this operation are important because this is the first large scale use of PAPP in New Zealand. Staff time spent baiting was significantly less than an equivalent live-trapping operation required to control feral cats. The network of 287 bait stations is now in place across the Poutiri Ao ō Tāne project area, potentially making future control using PAPP more cost-effective. Additionally, a toxin-based tool may target individuals who wouldn't otherwise be caught in traps.

Despite the high amount of bait take in this operation, for species sensitive to predation by feral cats, a 39% reduction is unlikely to achieve a population response. Given that immigration of feral cats following an operation can occur quickly (Bengsen et al. 2012), the timing of a control operation could be critical. For example, control could be timed to coincide with critical times in the life cycle of vulnerable native species, e.g. breeding or fledging.

We are unaware of any long-term study in New Zealand that has followed cat abundance through repeated (e.g. annual) cycles of toxic baiting. Monitoring annual baiting operations through time could answer valuable research questions. For example, future research could investigate the influence of rabbit abundance on the effectiveness of baiting, whether repeated application of poison baits leads to selection for individuals that do not take baits, and whether cat control leads to any perverse responses (e.g. mesopredator release of mustelids; Garvey 2016).

As predator control operations across New Zealand increase in scale, finding low-cost and varied tools for feral cat control is essential. Our results suggest that PAPP may provide a useful and cost-effective control tool for feral cats in New Zealand.

Author contributions

NdB conducted analyses and wrote the paper; AG, KM and MM contributed to study design, analysis and writing.

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