This programme demonstrated the importance of collaborative fox control programmes and the community ownership of the fox damage issue. The project was initiated by community members and was overseen by a committee made up of members from many stakeholder groups including local and state agencies, and the general public. As an alternative fox control programme for small holdings, the organisers as well as most of the participants believed this type of group programme was effective. Many more landholders were able to participate than one based on 1080 baiting, so a larger, more continuous area could be covered.

Unfortunately, however, this programme may have suffered from the same problem as those group baiting programmes that only occur once a year, with some respondents reporting that reduced sightings and impacts only lasted for 3–6 months, after which time the fox population began increasing again. The effectiveness of baiting programmes has been shown to increase when control is applied twice a year (McLeod *et al.* 2010) to cause maximum disruption to both the breeding and migration stages of the fox's life cycle. Funding and labour limitations prevented conducting this programme across the whole area twice a year. However, this should be considered to improve the programme's effectiveness over the longer term.

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Testing target-specific bait delivery for controlling feral pigs in a tropical rainforest

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Summary

Mitigation of feral pig (*Sus scrofa*) impacts in Australia's Wet Tropics World Heritage Area has been impeded by the lack of a target-specific method for delivering toxic baits in the region. This study evaluated methods to reduce bait-take by susceptible nontarget species without inhibiting bait-take by pigs, to enable more effective pig management. We predicted that dingoes would not select an unprocessed corn bait and that other potential nontarget bait consumers would be unable to access the same bait presented under a lightweight cover. Neither of these methods was expected to reduce bait selection or access by pigs. We tested these predictions by monitoring animal interactions with covered and uncovered corn baits, and covered corn and manufactured baits. Use of corn as a bait substrate effectively prevented bait-take by dingoes. Covering baits substantially reduced bait-take by other nontarget species and completely prevented nontarget bait-take when uncovered feed was provided simultaneously. The corn bait preparation was highly acceptable and accessible to feral pigs. We conclude that the methods evaluated here could enable the consideration of poison baiting as a viable method for controlling feral pigs in the World Heritage Area, where it has previously been unavailable.

Introduction

The feral pig (*Sus scrofa*) is regarded as the most important vertebrate pest in the rainforests of the Wet Tropics World Heritage Area (WTWHA) (Harrison & Congdon 2002); however, the mitigation of pig impacts has been hindered by a lack of effective and target-specific toxic baiting methods (Poon *et al.* 2007). Species of conservation significance, such as the Southern Cassowary (*Casuarius casuarius*) and Spotted-tailed Quoll (*Dasyurus maculatus*), are of particular concern. Methods currently recommended for feral pig baiting (Wet Tropics Management Authority 2004) have not been rigorously tested, and may imperil cassowaries because they recommend using poisoned bananas in open-topped containers. Trials of a commercially manufactured feral pig bait indicated that the bait was not yet useful for widespread use in the region because of the high potential for adverse impacts on nontarget species, particularly Dingo (*Canis lupus dingo*), and the low potential for consistent impacts on feral pig populations (Bengsen *et al.* 2010, 2011). In this follow up study, we aim to identify and evaluate baiting methods to decrease the risk of poisoning dingoes and other nontarget species, while increasing bait-take by pigs.

Based on a comparison of traits relating to the encounter, selection and access of baits by feral pigs and dingoes (following Bengsen *et al.* 2008), we predicted that an unprocessed starch-rich bait would not be acceptable to dingoes because dogs have a low capacity to digest complex carbohydrates. We also predicted that covering such a bait with a physical barrier that could be removed by a powerful animal using a head-lifting motion would prevent access by small-bodied nontarget omnivores and that neither of these features would reduce bait-take by pigs. Here, we experimentally test these hypotheses by monitoring animal–bait interactions in a rainforest system in the northern World Heritage Area.

Methods

Two trials were conducted in lowland rainforests of the Daintree region between June and July 2009. For the first trial, we established 45 bait sites in areas showing signs of recent pig activity, to test whether dingoes would consume a starch-rich bait and to test the efficacy of a light plastic cover as a barrier to small nontarget omnivores. Areas with abundant pig sign were spatially restricted in the study area, so bait sites were clustered within blocks (min. = 3 sites per block, max. = 7), with at least 50 m between neighbouring sites. At each site we set two aluminium foil trays containing 1.2 L of soaked cracked corn on a 1 × 2 m sandplot. We covered the corn with 45 g of copra meal to conceal it from birds, and to serve as an olfactory attractant to pigs. We placed a semi-transparent plastic box (34 × 46 cm wide × 24 cm high, 720 g) over one tray at each site, secured with a 20-cm tent peg on two opposing sides. Boxes were perforated with two small holes on each side to disseminate odours. We monitored 20 sites with motion-activated cameras (GameSpy 100; Moultrie Feeders, Alabaster, AL, USA). We visited each site daily for three consecutive days to record the volume of bait taken from each tray, and the presence of animal sign on sandplots and camera records. Bait was replenished as required to ensure that 1.2 L was available each day.

We used a linear mixed effects model to estimate the amounts of corn consumed per day by nontarget species other than dingoes. Models included a fixed effect for bait type (covered, uncovered) and a random site effect, nested in block, to account for autocorrelation.

In the second trial, we tested whether corn was less acceptable to dingoes than manufactured baits, and at least equally acceptable to pigs. We established 65 new bait sites, clustered in 14 blocks (min. = 3 sites per block, max. = 8). At each site we established a sandplot and a covered tray of corn, prepared as for the first trial. We also placed three nontoxic PIGOUT® or HOG-GONE® baits (Animal Control Technologies, Somerton, Vic., Australia) on the plot, covered with a box in the same manner as the corn. The PIGOUT® bait is a cereal-based cylindrical bait weighing about 250 g (described in detail by Cowled *et al.* 2006). HOG-GONE® baits were similar to PIGOUT® baits, but smaller (200 g) and more rigid. Thirty-two sites were monitored with cameras. We visited each site for eight consecutive days and recorded the volume of corn taken; the extent to which manufactured baits had been eaten, scored using a four-point scale (0 = bait not bitten, 1 = bait bitten to a depth <0.5 cm, 2 = bait bitten >0.5 and <2 cm, 3 = bait bitten >2 cm and 4 = bait missing or consumed), and the presence of animal sign on sandplots and cameras. It is unlikely that all baits classified as missing were consumed, as previous studies showed that dingoes often cached manufactured baits (Bengsen *et al.* 2011), and other animals could have moved baits from the site without consuming them. Bait was replenished as required, and all bait was replaced after 4 days.

We expressed the amounts of corn bait consumed by dingoes or pigs during the second trial into manufactured bait equivalents, such that 0.4 L of corn equalled one manufactured bait. Both of these units would contain 72 mg of sodium fluoroacetate (compound 1080) in their toxic form, and there were three units of each bait type available each site day. For each site day where pigs consumed bait, we calculated the difference in bait equivalents consumed between the corn bait and manufactured bait and used this figure as the response variable in a linear mixed effects model to estimate the preference for corn bait relative to manufactured baits. For dingoes, we reversed the operation to estimate the expected preference for manufactured baits relative to corn baits at each site where dingoes consumed bait. Both models used random site and block effects to account for autocorrelation. We used logistic regression to test whether the proportion of sites at which pigs and dingoes consumed both bait types increased over the 8 days of bait exposure. Regression models contained a random block effect to account for spatial aggregation.

We used log-linear mixed effects models to test whether the rates of manufactured bait consumption differed between PIGOUT® and HOG-GONE® baits for feral pigs and dingoes. Site days at which no baits were consumed were excluded. All models were implemented using the lme4 package (v 0.999375-18) for program R (v 2.6.1) (R Foundation for Statistical Computing, Vienna, Austria).

Results

In the first trial, tracks and camera records showed that bait sites were visited by feral pigs, dingoes, Fawn-footed Melomys (*Melomys cervinipes*), native rats (*Rattus* spp.), White-tailed Rat (*Uromys caudimaculatus*), Northern Brown Bandicoot (*Isoodon macrourus*), small birds, megapode birds (*Megapodius reinwardt, Alectura lathami*), Yellow-spotted Monitors (*Varanus panoptes*) and small lizards. All seven photographs of pigs at bait sites were of lone animals. No covered corn was consumed by any nontarget animal, whereas an average of 0.1 ± 0.01 L of uncovered corn was consumed by nontarget species per site per day. The intraclass correlation coefficient (ICC) within blocks was 0.26, indicating that the proportion of variance explained by differences within blocks was relatively low. Dingo sign was recorded at sandplots on 17 site days (12.6% of all site days). An individual dingo was recorded consuming up to 0.05 L of uncovered corn once, but this individual never returned to the site, and there was no evidence of dingoes eating corn on any other occasion. Data were too sparse to compare the consumption of covered and uncovered corn by pigs, but pigs never ate uncovered bait without also eating covered bait.

In the second trial, sandplots and camera records showed that bait sites were visited by feral pigs, dingoes, rodents, Northern Brown Bandicoot, small birds and small lizards. Feral pig sign was observed at bait sites on 105 occasions (20% of site days). Camera records showed group sizes of up to four pigs (once), but most records were of pairs (62%) or lone pigs (30%).

Pigs were 1.5 times more likely to eat the corn bait formulation than manufactured baits and ate an average of 1.1 ± 0.58 more bait equivalents per site day in corn than manufactured baits (t_{84} = 1.966, P = 0.03). The proportion of variance explained by differences within blocks was high (ICC = 0.86). Pigs ate manufactured baits only where they also ate corn, and usually took either all manufactured baits or none. Pigs usually ate all corn available, but left 0.1 L uneaten on four occasions and 0.7 L once during 520 bait days. The proportion of sites at which pigs consumed corn bait increased over the eight consecutive days of bait exposure without reaching an asymptote, but did not increase for manufactured baits (Fig. 1a).

Dingo sign was recorded at bait sites on 78 occasions in the second trial (15% of site days). Dingoes did not eat any corn, but ate manufactured baits on 46% of the occasions that they approached bait sites (Fig. 1b), consuming an average of 2.2 ± 0.21 baits each time. After 8 days, dingoes were removing manufactured baits each time they

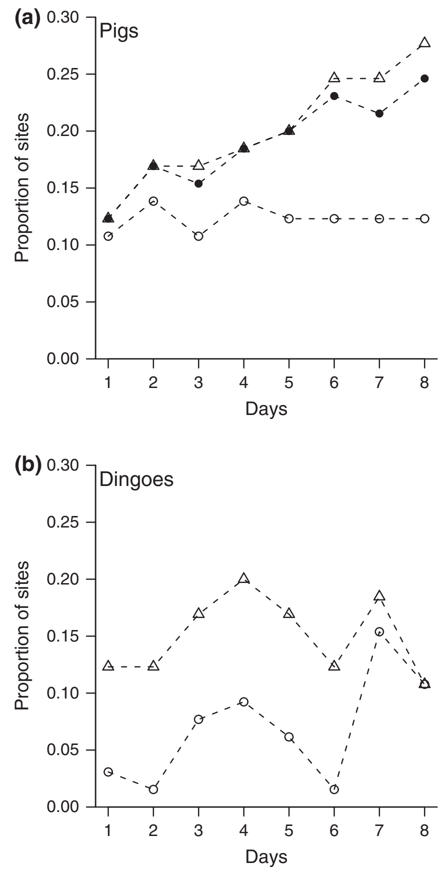

Figure 1. Proportion of sites at which (a) feral pigs and (b) dingoes encountered baits (Δ) and consumed corn bait (●) and manufactured baits (○) over eight consecutive days of bait exposure in a tropical rainforest.

encountered them (Fig. 1b). Neither pigs nor dingoes showed any difference in the expected number of baits consumed between PIGOUT® and HOG-GONE® baits (feral pig $z = 0.426$, $n = 64$, $P = 0.67$; Dingo $z = 0.738$, $n = 36$, $P = 0.46$).

Small nontarget mammals burrowed underneath boxes to access corn bait 41 times (8% of site days), and manufactured baits 13 times (3% of site days). Small mammals consumed up to 0.2 L of corn on these occasions, and bit into manufactured baits to a depth sufficient to access the toxin that would be incorporated into toxic versions of the baits (>2 cm) once.

Discussion

Use of cracked corn and copra as a bait substrate appeared to largely prevent bait-take by dingoes, and, in the second experiment, enhanced bait-take by feral pigs relative to manufactured bait. The high acceptability of manufactured baits to dingoes was consistent with previous studies in the WTWHA (Bengsen *et al.* 2010, 2011), but not with results from other Australian regions (Cowled *et al.* 2006).

Use of a plastic box to cover baits greatly reduced bait-take by small nontarget omnivores. We were unable to test whether boxes prevented cassowaries or quolls from accessing bait, as none of these animals approached bait sites. Covers were most effective when an alternative decoy food source was presented adjacent to the covered bait, but rodents sometimes burrowed beneath boxes to access bait when no alternative feed was provided. Covers also appeared to substantially reduce the number of manufactured baits taken by dingoes, compared with previous studies in the region (Bengsen *et al.* 2010, 2011). However, this effect diminished over time as dingoes learned how to access baits.

Feral pigs showed a clear preference for corn topped with copra meal over manufactured baits and were able to remove the covers to access bait. Lone pigs usually consumed all 1.2 L of corn bait presented and always consumed enough bait to ingest more than one nominal lethal dose. However, small amounts of bait sometimes left uneaten could still pose a risk to some nontarget animals, and a self-resetting physical barrier would be preferable to the simple devices we tested. The increasing proportion of sites at which pigs consumed corn bait over time was probably mostly attributable to more pigs locating sites, as examination of camera records showed that the group sizes of pigs visiting some bait sites increased over time.

The greatest technical impediments to the use of toxic baiting for pig management in the WTWHA have been the potential for accidental poisoning of nontarget species, and low bait-take by feral pigs. The use of a corn bait formulation presented beneath a plastic box, with a small decoy free feed, might overcome both impediments. The amount of decoy feed should be about 0.5 L, which is almost twice the maximum amount of corn bait consumed by nontarget species in this study, but not so much that it should cause satiety in pigs. Too much decoy feed might allow pigs to become satiated before they consume all of the toxic bait that they uncover. As well as the nontarget hazard this would pose, it could cause pigs to ingest sublethal doses and develop conditioned bait aversions. The effects of any baiting program on nontarget species, feral pigs and the damage caused by pigs should be experimentally evaluated before being widely adopted in the region.

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