# Evaluating the effectiveness of aerial baiting operations for rodent eradications on cliffs on Gough Island, Tristan da Cunha

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## SUMMARY

The use of helicopters for spreading bait pellets in rodent eradication operations for conservation programmes is increasing. While aerial applications generally have a high success rate at eradicating rodents, operations that tackle extensive areas of steep terrain (slopes >50°) are more challenging, as the effectiveness of spreading bait pellets at the targeted density in these areas is unknown. We undertook an aerial baiting trial on Gough Island, where predation by the non-native house mouse *Mus musculus* is devastating the globally important seabird populations. It is therefore critical to deliver bait to the island's large areas of vegetated cliffs that contain burrowing petrels and mice. Using a helicopter and bait hopper we spread non-toxic bait pellets on two areas of coastal cliffs and the adjoining flat ground, and measured the resulting density of pellets using teams of roped climbers and distance sampling. Compared with adjacent flat areas, the vegetated cliff areas retained an average 66-76% of pellets (lower 95% confidence interval 45-60%). While baiting rates on cliffs were lower than adjoining flat areas, the recommended best practice for aerial eradications prescribes applying two additional drops on steep areas. Consequently, current best practice would be sufficient to ensure coverage at densities at or above the targeted baiting rate. While these trials were focused on Gough Island, the results should be useful for eradication operations on other islands with cliffs with similar terrain and vegetation cover.

## BACKGROUND

The eradication of non-native mammalian predators has become a mainstay of island restoration efforts, with over 300 islands successfully cleared of rodents (Howald *et al.* 2007). Eradication operations, particularly those targeting rats *Rattus* spp. and house mice *Mus musculus*, typically utilize cereal pellets or bait blocks containing anti-coagulant toxins. Depending on the size and terrain of the island, bait is either distributed in bait stations, spread by hand or aerially broadcast with helicopters. The last option has become increasingly common as the conservation community tackles larger and more ambitious rodent eradications (Towns & Broome 2003).

Such aerial operations typically use helicopters and experienced pilots to fly GPS-guided flight lines while spreading swathes of toxic bait pellets from a modified agricultural bait hopper. A guide for best practice to maximise the likelihood of successful eradication was produced by the New Zealand Department of Conservation, and recommends that two applications of bait are made around three weeks apart, to ensure that any rodents surviving the first operation will encounter pellets from the second (Broome *et al.* 2011). To minimise the risk of gaps in bait coverage, flight lines overlap by 50%. It is also usual for at least two additional bait swathes to be applied around the perimeter of the island. Aerial operations on islands with large areas of cliffs and steep terrain (defined as slopes > 50°; Broome *et al.* 2011) pose additional challenges, due to the increased surface area (in comparison to the two dimensional planar area) and an unknown proportion of pellets landing on steep terrain and bouncing downhill, thus reducing targeted bait density. To mitigate these two factors, cliffs and steep slopes are defined as "special treatment areas" and receive a further two bait applications (Broome *et al.* 2011).

Aerial operations have often proved successful in eradicating non-native rodents, including on islands with cliffs and steep slopes (Towns & Broome 2003, Broome 2009). However, 10 out of 30 projects targeting eradication of mice with aerial baiting have failed (DIISE 2014) and the reasons for the reduced success of mouse eradications are unclear. In comparison to rats, mice require a greater dose of anticoagulant toxin and have smaller home ranges (Phillips 2010, Cuthbert *et al.* 2011a). Consequently, it may be critical to apply bait at a higher density and ensure there are no gaps in bait coverage. This may be even more difficult on islands with complex and steep terrain.

The relative lack of knowledge on the effectiveness of spreading bait on steep slopes and cliffs has been an obstacle for planning and undertaking an eradication operation of the non-native house mouse *Mus musculus* on Gough Island. This large island (6400 ha) is part of the UK Overseas Territory of

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**Figure 1.** Gough Island, indicating the extensive vegetated coastal cliffs.

Tristan da Cunha, in the central South Atlantic Ocean, and has steep, vegetated terrain (Figure 1). Here predation by mice has had a large negative impact on the bird populations and the whole ecosystem (Cuthbert & Hilton 2004, Angel & Cooper 2006, Wanless *et al.* 2007). Predation by mice has caused two bird species to be listed as Critically Endangered and is causing widespread declines in the formerly abundant populations of burrowing petrels (Cuthbert *et al.* 2013). A recent appraisal of islands in the UK Overseas Territories where eradication of non-native species is technically feasible ranked Gough Island as the highest priority (Dawson *et al.* 2014). To date, preparations for a mouse eradication have determined bait preference and toxicity of brodifacoum (Cuthbert *et al.* 2011a), established that caves are unlikely to provide refugia to mice (Cuthbert *et al.* 2011b), and produced a feasibility study and draft operational plan (Parkes 2008, Torr *et al.* 2010). The key remaining factor is an assessment of whether it is possible to effectively apply bait pellets into the home range of all mice on the island's steep vegetated cliffs.

## ACTION

In order to evaluate the effectiveness of aerial operations at delivering bait pellets to cliffs and steep slopes, we undertook two aerial baiting trials on Gough Island and measured the density of bait pellets on steep vegetated coastal cliffs (average slope 69-78°; Table 1) compared with flatter vegetated terrain in adjacent areas (average slope 5-10°; Table 1). The two trial sites were flat area and steep cliffs that were both covered in tall tussock grasses (primarily *Spartina arudinacea*) and shorter sedges (*Carex insularis* and *Scirpus bicolor*), ferns (mainly *Asplenium obtusatum*) and forbs typical of coastal vegetation on the island (Wace 1961). These flat areas and cliffs hold large numbers of great shearwater *Puffinus gravis* burrows as well as house mice. Vertical cliffs of bare rock were not targeted as we already knew that bait retention there would be near zero; fortunately these areas were also unlikely to support mice. For logistical reasons the trial area was in the southeast of the island where the coastal cliffs are relatively low (40-60 m) compared with the west and north coasts where they reach 200 m in height. Slope angle and vegetation of the south-eastern cliffs were similar to those elsewhere, suggesting that the retention of pellets on the trial areas was likely to be representative. We used a bait spreading hopper (manufactured by Heli Otago, New Zealand) and pellets (manufactured by Bell Laboratories, Wisconsin, USA) that have been used in many previous successful eradication operations. A Bell 212 helicopter was overseen by Peter Garden, one of the world's most experienced eradication pilots. The only difference from a real operation was that we used non-toxic bait.

At each trial site bait pellets were spread at a targeted ground density of 8 kg/ha along 500 m of coastal cliffs and adjacent areas of flat ground measuring 500 x 200 m. On the same day as the bait spreading (to minimise bait loss to mice) we recorded the density of pellets on the ground (in an approximately 2 ha plot) and on the cliffs (an area 50 m wide by 30-50 m high) in the core of the trial area. The density of bait pellets was measured by trained rope access workers using distance sampling. On the cliffs the vertical line of the climbing rope was used as a transect line. A climber slowly descended the rope searching carefully for pellets and recording their perpendicular distance from the rope (to the nearest 5 cm), as well as the total length of drop. Because climbers abseiled down and then had to climb back up the ropes, pellets were recorded during both the descent and ascent. The same procedure was followed on the adjacent flat areas of ground. Twenty-three transect lines measuring a total of 850 m were surveyed on the two cliff areas, and 30 transect lines measuring a total of 960 m were surveyed in adjacent flat areas of ground (Table 1). To evaluate between-observer variability and determine if distance sampling was required, we also undertook eight independent transects on flat ground where a predetermined number of bait pellets had been randomly scattered along the transect line. This trial indicated that there was relatively little variability between observers in finding pellets (coefficient of variation = 40%), but that due to the dense vegetation observers only found 34 ± 12% (± S.D.) of pellets.

Results were analysed using the programme Distance 6.0 (Thomas *et al.* 2009), including data on transect number, length and perpendicular distances. Perpendicular distances were binned into categories of 0-20 cm, 21-40 cm, etc. up to the maximum observed distance of 240 cm. We followed the conventional Distance sampling procedure detailed in Thomas *et al.* (2009) and ran models with Uniform, Hazard and Half-normal detection functions, and with cosine, simple polynomial and hermite polynomial expansion series. We used Akaike's Information Criterion (AIC) to compare models, selecting the model with the smallest AIC in the model set.

## CONSEQUENCES

Following the aerial application of bait, lower densities of bait pellets were found on the two areas of cliffs than the adjacent flat areas. The vegetated coastal cliffs on Gough Island retained an average of 66-76% of pellets compared to adjacent flat areas of ground (Table 1). The lower 95% confidence interval of the estimated bait density for each cliff application suggests bait retention on cliffs could be as low as 45-60% in comparison to the flat areas (Table 1). While the retention of bait on cliffs was lower than the baiting rate on flat ground, current recommended best practice for aerial eradications advises two more applications of bait in all steep areas (slopes > 50°) (Broome *et al.* 2011). If no gaps in coverage occurred, then the current best practice of applying three drops would be sufficient to ensure coverage at, or above, the targeted baiting rate.



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**Table 1.** Site details, sampling strategy and bait density at the two trial locations.

| Site | Area | Slope° ± S.D. | Number of transects | Total transect length (m) | Bait density (pellets/ha) (95% CI) | Pellet retention on cliff area relative to flat area (%) |
|---|---|---|---|---|---|---|
| 1 | Flat area | 10° ± 6° | 20 | 640 | 2210 (1879 - 2599) | 76.0 |
| | Cliff area | 69° ± 10° | 12 | 546 | 1679 (1331 - 2118) | |
| 2 | Flat area | 6° ± 2° | 10 | 320 | 846 (505 - 1417) | 66.4 |
| | Cliff area | 78° ± 9° | 11 | 304 | 562 (382 - 826) | |

## DISCUSSION

This is the first attempt that we are aware of to field test a key assumption of an increasingly common conservation action: the adequacy of coverage of rodenticide bait pellet application in steep terrain using aerial drop. Our results indicated a lower retention of pellets on vegetated cliffs in comparison to similarly vegetated flat areas of ground. However, the current recommended best practice of applying two additional bait applications to steep ground is sufficient to overcome the lower bait retention in these areas.

While the results are of key relevance for operational planning for Gough Island, a number of important caveats need to be considered. Firstly, bait pellets were measured on the cliffs on the day of spreading; we did not record the percentage of pellets remaining with the passage of time. Secondly, the days when pellets were spread were selected to have relatively low wind speeds; high wind and rain may further reduce the retention of pellets on steep slopes. Lastly, for logistical purposes, the trials were undertaken on relatively small cliffs.

Despite these caveats, our results provide the first detailed information on bait retention on Gough Island's cliffs and will aid in operational planning for a future eradication attempt. These trials may also provide useful information for other eradication operations, particularly those on cold-temperate and sub-Antarctic islands with similar vegetation and cliffs to Gough Island.

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