Animal Health Board Project No. R-80629 (sub-project)

Relative effectiveness of the Judas technique in rapidly reducing pig numbers in part of Molesworth Station: An operational trial.

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Summary

Project and Client

This operational research project was undertaken to fulfil an objective within a larger Animal Health Board (AHB)-funded project: "Cost-effective control of Tb in the Northern South Island High Country (NSIHC): Identifying the habitats and vector species requiring control" (Project R-80629). This sub-project aimed to determine whether use of radio-tagged Judas pigs provided a more cost-effective tool for rapidly reducing pig numbers in the semi-arid habitat characteristic of Molesworth Station than did simple unaided aerial hunting. It was undertaken by Landcare Research between September 2005 and February 2006 with joint funding from the AHB's research programme and their LIPS operational programme.

Objectives

- To quickly reduce pig numbers in one part of Molesworth Station in late 2005, to provide one of the experimental treatments required for the larger study (operational-funded)
- To determine whether use of the Judas technique is more cost effective than unaided aerial hunting for pig control (research-funded).

Methods

- *Judas pig capture and radio tagging.* Nine resident pigs were captured and radio-tagged using a helicopter-and-dogging approach.
- *Quantifying relative efficiency:* On six subsequent occasions at about 2-weekly intervals, the area was aerially hunted for 2 hours. During the first half of this time, the hunters did not use the radio tags to help locate pigs. During the second half, the Judas pigs were systematically re-located and any untagged pigs associated with them were shot wherever possible. The number of pigs seen and killed, their location, and the extent of ground cover at the kill site were recorded. Once hunting was completed, whole pigs or pig heads were recovered for necropsy (for other projects).

Results

- In the initial capture phase, nine pigs (6 female and 3 male) were captured and 18 pigs were shot during c. 6 hours of flying time. Capture and tagging of the Judas pigs therefore required only 2–3 hours of flying time over and above the cost of normal unaided hunting.
- A total of 55 untagged pigs were seen during six subsequent hunting sorties. Of these, 47 were shot, 16 during unaided hunts and 31 during Judas hunts. For these sorties, Judas hunting was more cost effective (5.4 ± 1.7 kills/hour) than unaided hunting (3.2 ± 1.24 kills/hour). Adding the time of capture, the kill rate figure for Judas hunting reduced only slightly to 5.0 ±1.5 pigs/hour.
- During unaided hunting, the scrub-cover-at-first-sighting scores for the pigs seen averaged 53.5 ± 6.9% (range 10–80%). The average cover score was much higher (91.3 ± 2.4%; range 50–100%) for Judas hunting, indicating that Judas associates were generally killed in much thicker cover.
- The Judas animals became extremely wary of the helicopter as the study progressed. On several occasions Judas pigs could not be sighted in the vegetation despite the helicopter hovering c. 2 m above them for up to 10 minutes, and with shots fired into the ground

beside them. The six Judas females were re-located on an average of four times each with 0.70 associates killed per re-location, while the three males were re-located an average of three times each with 0.66 kills per re-location). The minimum convex polygon area encompassing all of the re-locations of each pig ranged between 2 and 135 ha.

- Approximately 93 pigs were removed from the 68 km^2 over a 5-month period, with 20 of these being killed by ground hunters just before this aerial hunting trial began. Subjective assessment of the abundance of pig sign and a rapid decline in hunting success rates suggested that a large proportion of the pig population was removed during this study.
- One frustrating aspect of the trial was our inability to re-locate all of the radio-tagged pigs during each hunt, as a consequence of technological and experience limitations. None of the Judas animals lost their transmitters.

Conclusions

There are good (albeit subjective) indications that the trial substantially reduced pig numbers, thus satisfactorily meeting one of the experimental conditions required for the larger study.

The Judas technique was moderately more cost effective than unaided hunting. Judas hunting would likely have been even more cost effective if it had not always been preceded by the disturbance created by an hour or more of unaided hunting, by not having a one-hour time constraint, and by greater skill in quickly and reliably re-locating the radio-tagged pigs.

Kill rates declined rapidly after the first two hunting sessions, probably because of both a lower pig density and an increased avoidance of the helicopter by survivors. The greatest strength of the Judas technique for aerial hunting is perhaps that it provides a way of aerially hunting pigs in dense cover. This minimises the effect of increased wariness on hunting success and increases the likelihood of eliminating whole family groups even when they inhabit heavy cover. There was no evidence of a major difference between the sexes in their "productivity" of killable associates.

Recommendations

The Judas technique should be used for pig control and/or surveillance where pig density is low, and where tall (>2 m) vegetation cover is sufficiently patchy to enable most pigs to be forced into nearby open areas by the helicopter before shooting.

We recommend:

- Use of small helicopters (e.g. Robinson R-22) for accessible low-altitude areas, but larger machines in more remote, mountainous areas.
- Use of pilots with extensive radio-tracking experience wherever possible, or at least use of dual headsets so that the shooter can also assist with radio tracking.
- That the Judas pig technique is routinely used to complement ongoing pig-trapping programmes. The results did not indicate that females were much more effective than males as Judas animal, or that breeding pigs were more effective than non-breeding pigs, so, in the interest of tagging efficiency, we recommend using all captured pigs where ongoing control is planned. Where eradication is the aim, however, it would seem advisable to use only neutered males so that if any transmitters fail the reproductive potential of the resulting untraceable animal (which is likely to be very difficult to kill using unaided hunting) is zero. Males are recommended here simply because they are easier to neuter in the field.

1. Introduction

This "operational research" project was undertaken to fulfil an objective within a larger Animal Health Board (AHB)-funded project: "Cost-effective control of Tb in the Northern South Island High Country (NSIHC): Identifying the habitats and vector species requiring control" (Project R-80629). This sub project aimed to determine whether use of radio-tagged Judas pigs provided a more cost-effective tool for rapidly reducing pig numbers in the semi-arid habitat characteristic of Molesworth Station than did simple unaided aerial hunting. It was undertaken by Landcare Research, Lincoln, between September 2005 and February 2006 with joint funding from the AHB's research programme and their LIPS operational programme.

2. Background

Pigs are increasingly being used as sentinels to detect and quantify the levels of bovine tuberculosis (Tb) in wild animals. In some places landowners and vector control managers also wish to reduce pig densities to decrease any potential risk of Tb persistence and spread and/or any threats pigs might pose to environmental or production values. However, obtaining pigs for necropsy or simply killing them as part of control operations can sometimes be expensive, creating a need to identify the most cost-effective hunting technique for the various habitat types in which pigs are perceived to be a problem. In this study, we compared the cost-effectiveness of unaided aerial hunting with that achieved by aerial hunting, using radio-tagged "Judas" pigs to help locate and kill survivors.

The study was undertaken in a small, largely unforested part of Molesworth Station, primarily to service a larger investigation of the eco-epidemiology of Tb in that area. An important question on Molesworth Station (and the northern South Island high country (NSIHC) generally) is whether pigs play some role in sustaining or spreading Tb there. One objective of the larger Molesworth project (R-80629) is therefore to test empirically whether pig control alone substantially reduces the level of infection in wildlife. The experimental design developed to test this hypothesis required a substantial reduction in pig density in one area, so that the effect of that reduction on the subsequent trends in Tb prevalence in young pigs could be compared with the trends observed under two other treatments (no control at all, and with aerial poisoning of possums). Pre-treatment surveys were completed in 2004, and the possum-poisoning treatment was successfully imposed in winter 2005. However, we were unable to achieve the desired level of pig control in the pig-control treatment block. Additional control was needed.

The AHB agreed to operational funding to achieve that, and research funding to use the opportunity to determine whether the Judas approach was likely be more effective than the simple, unaided, aerial hunting technique traditionally used on Molesworth Station. While aerial shooting is cost effective when pig densities are high, the cost per kill climbs steeply when pig numbers are reduced because most helicopter time is eventually spent looking for pigs rather than killing them (Choquenot et al. 1996). The Judas method aims to reduce this

search cost by enabling hunters to quickly find survivors. The method relies on the strong tendency for pigs (as social animals) to aggregate in groups. A small number of pigs are captured, radio-tagged, and released. They are then re-located on subsequent occasions, and an effort made to kill any new associates found with them. The technique is particularly effective in open or shrubby habitats and its efficiency has been demonstrated in Central Otago (Knowles 1994), and more recently on the adjoining Muzzle Station where the efficiency of finding large family groups of pigs was shown while radio-tracking single radio-tagged sentinel pigs (I. Yockney pers. obs). The Judas Pig approach is also currently being used to help eradicate pigs from Santa Cruz Island, California (N. MacDonald, ProHunt NZ, pers. comm.).

This project therefore aimed to quantify the efficiency gains (if any) of the Judas technique compared with traditional or unaided aerial shooting, with the expectation that a positive outcome from this demonstration would lead to the uptake of the method where aerial pig control and/or carcass recovery was required in similar unforested habitats.

3. Objectives

- To quickly reduce pig numbers in one part of Molesworth Station in late 2005, to provide one of the experimental treatments required for the larger study (operational-funded)
- To determine whether use of the Judas technique is more cost effective than unaided aerial hunting for pig control (research-funded).

4. Methods

4.1 Study area

The area chosen for this work encompassed an area within Molesworth Station from Lake McRae to the northeastern boundary of the property (Fig 1). It comprised 6800 ha of scattered, but sometimes thick areas of matagouri (*Discaria toumatou)*, sweet briar (*Rosa rubiginosa)*, Spaniard (*Aciphylla* spp.) and mountain flax (*Phormium colensoi*). We used a systematic approach to cover most catchments within the study area, with hunting altitudes varying from 600 to 1300 m.a.s.l.

4.2 Capture of live pigs for radio tagging

All of the animal manipulations in this trial were covered under Animal Ethics Approval (AEC #02/10/3A).

Resident pigs captured from the area intended for pig control are considered to be more effective than pigs imported from elsewhere (McIlroy & Gifford 1997). We therefore used a helicopter-and-dogging method to live-capture resident pigs in September 2005, and attempted to obtain an even spread of pigs throughout the area (see Fig. 1). This method was first developed in May 2005 by Landcare Research to capture pigs for a Tb-host-status trial

being conducted as another part of Project R-80629. It involved using a helicopter, first to find suitable pigs, next to position a hunter and a single live-capture-trained dog on the ground nearby, and then using the helicopter to drive the pig back toward the hunter. Once caught, a radio transmitter glued to an ear-tag was quickly fitted to one of the pig's ears and a blue plastic cattle-ear-tag attached to the other ear to aid visibility. The pig was then sprayed on the back with marker dye and released (Fig. 2). In this trial we used a stainless steel male pin for fastening the Allflex radio transmitter ear tag (Sirtrack NZ Ltd) in an effort to reduce tag breakages (and subsequent transmitter loss), a problem that occurred in previous studies. Wherever possible, any additional pigs found with the captured animals during this capture phase were shot from the helicopter.

We successfully used both Robinson R-22 and R-44 helicopters (Amuri Helicopters, Hanmer), for live capture, with the dog carried in a pod mounted on the skid of the helicopter. To minimise animal stress and the time costs associated with pig capture, the pilot and ground hunter used ground-to-air radio contact to work closely together in mustering and capturing the pig as quickly as possible.

Nine pigs were radio tagged, with each capture taking an average of about 40 minutes of helicopter flying time. Most of this time (c. 75%) was required simply to find the pigs, with capture and release usually taking less than 5 minutes. Although we aimed to capture mainly sows (because McIlroy & Gifford (1997) recommend that locally tagged sows should be used), it was not possible to reliably identify the sex of the pig before it was captured, so three of the pigs captured were young males. At least two of the six sows were obviously pregnant. All nine of the pigs captured remained alive throughout the duration of the study.

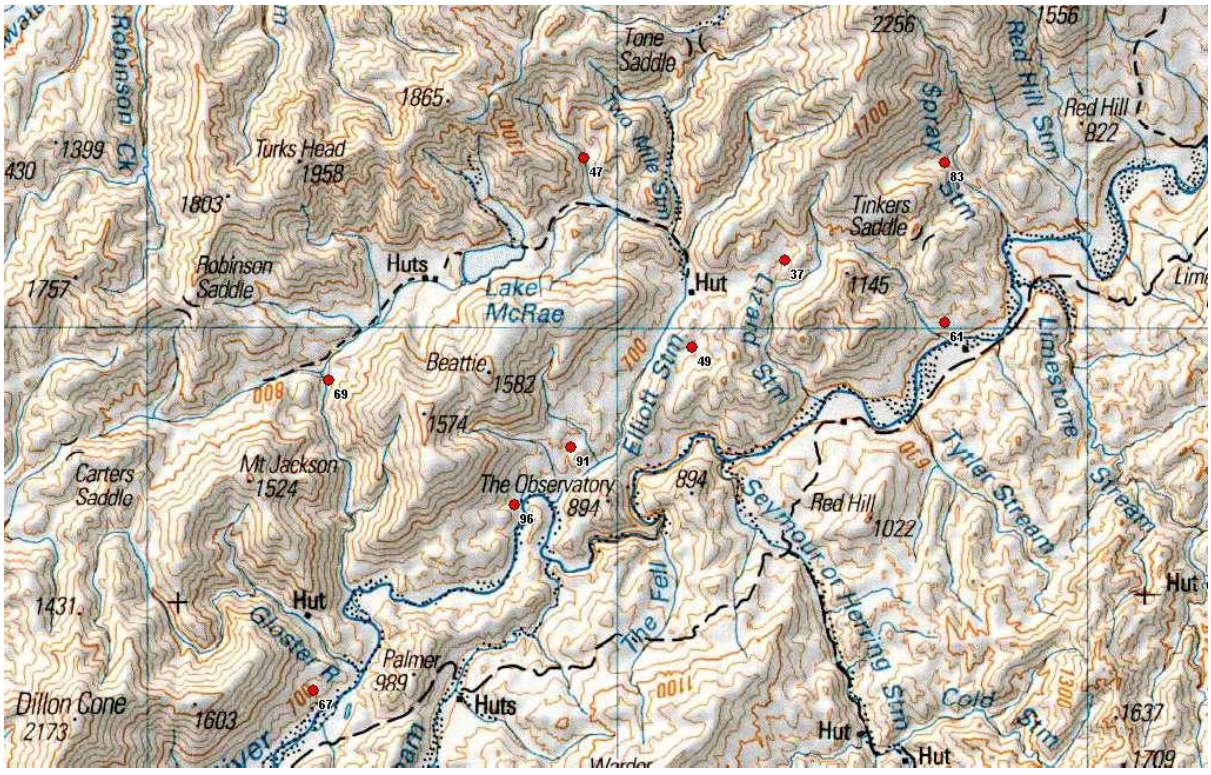

Fig. 1 Molesworth study area, showing the capture and release locations (red circles) of nine Judas pigs.

Fig. 2 A live-captured Judas pig, radio-transmitter tags in ear, sprayed with dazzle on the back and ready for release.

4.3 Aerial hunting

Subsequent aerial hunting was conducted using a Robinson R-44 helicopter. We had intended to use a smaller (cheaper) Robinson R-22, but the intended machine was not available. The pilot used during the study had substantial previous experience aerial hunting on Molesworth Station, but only limited previous experience with radio tracking from the helicopter. For radio tracking, the pilot used an ATS 2100 or Telonics TR-4 receiver and a three-element aeronautical aluminium Yagi aerial attached to the helicopter skid (Gregory et al. 2002). The pilot considered background noise (static) was worse when this equipment was used in this study than when used in an R-22 helicopter previously. Because of problems with electronic equipment two sessions were conducted with pilot and shooter using active-noise-reducing (ANR) aviation headsets (LightSPEED Aviation, Inc. Portland, Oregon) through a double adaptor and TR4 receiver.

On each of the approximately fortnightly hunting sessions, 2 hours were dedicated solely to hunting, with animals recovered for necropsy after the hunting was completed. In each session, the first hour was spent hunting "blind" (i.e. unaided by radio-telemetry) relying on pilot experience and visual skills alone to locate pigs. An attempt was made to shoot all

untagged pigs encountered, regardless of whether or not they were associated with tagged Judas animals. The GPS location and number of pigs in each group was recorded, and the percentage of scrub cover at the site the pigs were first seen was estimated. The number of pigs shot and the reasons why any escaped were also recorded.

During the second hunting hour on each session, an effort was made to re-locate all of the radio-tagged pigs, and kill their associates. Any other pigs not associated with tagged animals encountered during this hour were also shot wherever possible. "Judas" hunting was terminated after 1 hour even if not all the tagged pigs had been successfully re-located.

Once hunting had been completed, pigs were recovered for necropsy as part of project R-80629. Necropsies followed our now well established standard methods, with mycobacterium culture of the pooled mandibular lymph node of each pig. Results from this will be reported as part of project R-80629.

Hunting sessions were initially repeated fortnightly (as recommended by Sharp & Saunders 2004. (Unpublished) Aerial shooting of feral pigs. Standard Operating Procedures produced for NSW Department of Primary Industries), but the last two forays were conducted at monthly intervals to give the Judas pigs longer to find and associate with other pigs.

5. Results

5.1 Judas capture phase

In the initial capture phase, nine pigs were captured and 18 shot (either as associates of the pigs captured or incidentally when seen as the hunter moved between areas) during c. 6 hours of flying time.

Overall, it cost about 40 minutes ($500) of flying time to capture each Judas, and the ear-tag transmitters cost $350. The total cost per Judas pig is therefore likely to have been below $1,000, and this is offset somewhat by the 18 pigs killed at the same time. If all 27 pigs had been killed, we estimate that only about 4 hours of flying time would have been required to do this. Consequently, only about half the total flying time was an additional cost over and above the cost of normal unaided hunting.

5.2 Aerial hunting phase

Six aerial-hunting sorties were conducted between October 2005 and February 2006 (Table 1; Fig. 3). On each of the first five sorties, exactly 60 minutes were spent blind hunting, but the time spent Judas hunting was variable, depending on whether another re-location could be usefully started or the final one completed within the one-hour period. The final hunt was extended to 90 minutes to recover the four remaining Judas pigs that had not been found during the previous hunt. Three of these were successfully re-located and killed, but the fourth was never relocated.

Despite the marker spray initially applied to the Judas animals wearing off rapidly, the Judas pigs were readily recognised by both shooter and pilot. The bright-orange radio-tag was

usually clearly visible when the pig was moving away from the helicopter, while the blue cattle tag in the other ear was placed where it could be easily seen from front on. As a result, none of the nine Judas pigs were accidentally shot during the hunting phase.

Table 1 Summary of six aerial pig-hunting sessions on Molesworth Station between October 2005 and February 2006. Unaided hunting was not carried out on the final recovery trip (13 February). The number of pigs shot as associates of Judas (26 in total) is the number shot during Judas hunting minus the number shot unaided and the number of Judas pigs recovered during each Judas hunt.

		Unaided hunting		Judas hunting		
Date	Weather	No. of pigs shot	Hunt duration (min)	No. of Judas pigs re-located	No. of pigs shot	Hunt duration (min)
15 Oct	Overcast	2	60	5	15 (incl. 5 unaided)	68
31 Oct	Fine and calm	1	60	4	1	65
18 Nov	Fine and calm	3	60	8	3	55
15 Dec	Overcast, humid	8	60	8	5	58
20 Jan	Fine and calm	2	60	5	7 (incl. 5 Judas recovered)	85
13 Feb	Fine, NE breeze	–	–	3	8 (incl. 3 Judas and 3 unaided)	90
Totals		16	300		39	421

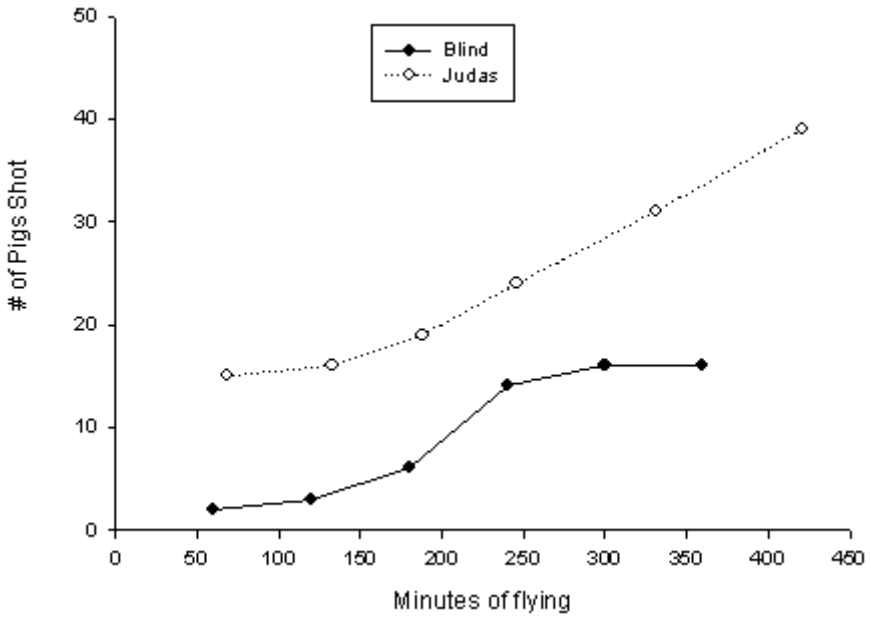

Fig. 3 Cumulative number of pigs shot per minute of flying by hunting method.

A total of 55 untagged pigs were seen during these six hunting sessions, of which 47 were shot (Fig. 4). The eight that escaped typically ran into thick scrub cover and could not be resighted. Four of the escapes were during unaided hunting and four during Judas hunting.

Overall, twice as many (31) untagged pigs were shot during the Judas hunts as during unaided hunts (16). The variability in kill between hunts and the small numbers of pigs killed preclude strong statistical inference, but the results are consistent with an improvement in the efficiency of hunting through use of Judas pigs.

For the 47 untagged pigs recovered for necropsy, the mean age was approximately 20 ± 1.8 (SE) months (range 3–42+ months). Of these, 45 had macroscopic lesions typical of Tb. In addition, all eight of the Judas pigs recovered had typical Tb lesions when killed. More detailed analyses of these prevalence data will be conducted as part of project R80629.

During unaided hunting, the scrub-cover-at-first-sighting scores for the pigs seen averaged 53.5 ± 6.9% (range 10–80 %). During Judas hunting the average score was higher (91.3 ±2.4%; range 50–100%), indicating that Judas associates were generally killed in much thicker cover (Fig. 5).

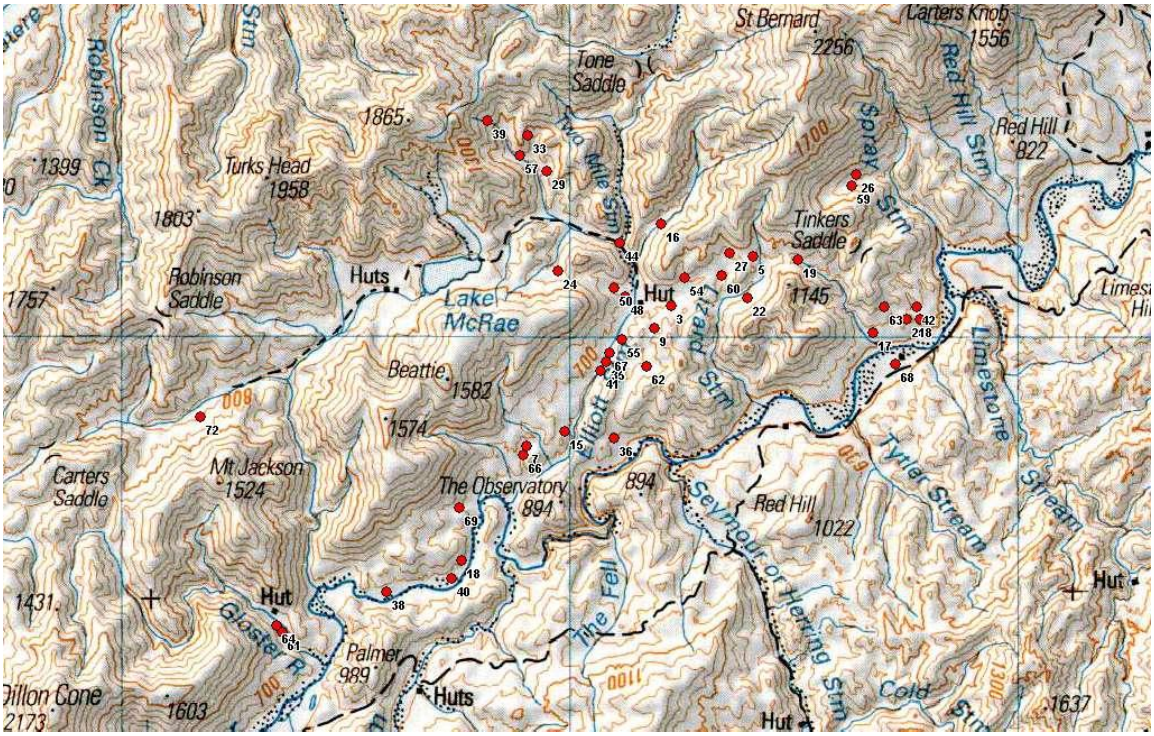

Fig. 4 Location and distribution of the 73 pigs shot within the study area. Many locations represent multiple animals shot. (Judas pigs = 8; initial hunt = 18; Judas hunts = 31; unaided hunts = 16).

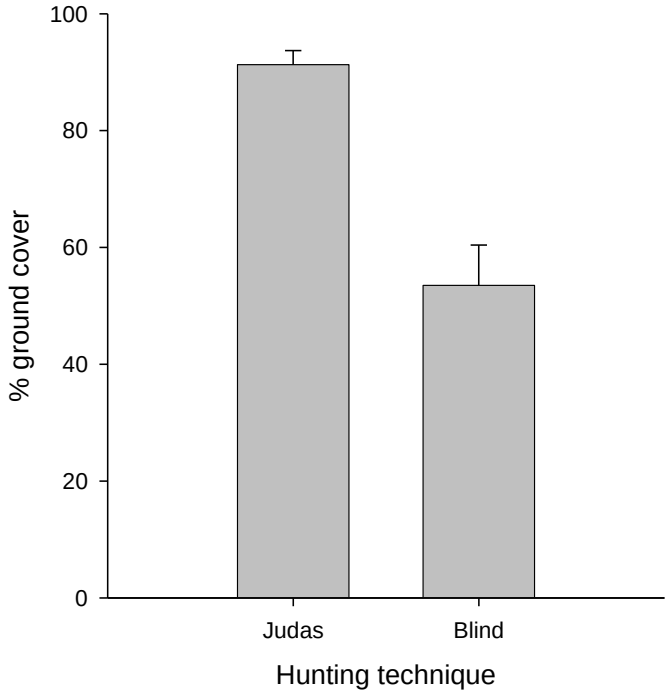

Fig. 5 Mean ground cover at the time of first 'sighting'. For the Judas technique, sighting is considered a positive re-location if ground cover is 100%.

5.3 Behaviour of Judas pigs

There was no evidence of a major difference between the sexes in their "productivity" of killable associates. The six females were re-located an average of four times with 0.70 associates killed per re-location, while the three males were re-located an average of three times each with 0.66 kill per re-location (Table 2). The minimum convex polygon (MCP) area encompassing all of the re-locations of each pig (Table 2) ranged between 2 and 135 ha, which is at the lower end of the scale of home range sizes reported elsewhere in New Zealand (Nugent et al. 2003).

Table 2 Sex, ID number, age, re-location area, number of re-locations, and the "productivity" of each Judas pig.

Sex	Animal ID (channel no.)	Age (months)	MCP home range area (ha)	No. times located	Total no. associates shot
Female	96	42+	135	3	1
Female	69	18	2	2	2
Female	67	22	67	4	2
Female	83	31	17	5	3
Female	49	42++	56	5	4
Female	37	18	47	5	5
Male	91	N/A	N/A	1	1
Male	61	12	43	3	1
Male	47	33	31	5	4

Not surprisingly, the Judas animals became extremely wary of the helicopter as the study progressed. On several occasions Judas pigs could not be sighted in the vegetation despite the helicopter hovering c. 2 m above them for up to 10 minutes, and with shots fired into the ground beside them. Similar avoidance behaviour was reported by Knowles (1994). We assumed on these occasions that the Judas pig was alone, as whenever unmarked pigs were known (from momentary glimpses) to be associated with the Judas, the level of disturbance was always sufficient to force them out into the open. At the end of the study, it was extremely difficult to force the Judas animals out of hiding, often taking up to 15 minutes of flying time to enable a shot to be taken. This added considerably to the cost per kill in this phase of the operation.

5.4 Comparison of cost effectiveness

The main cost in any aerial shooting campaign is the cost of the helicopter flying time, so our comparison of the cost-effectiveness of the two hunting methods is based simply on the numbers of pigs shot per hour of flying time. The flying time getting to and from the study area is excluded.

During the hunting phase, kill rates varied from 1 to 15 pigs /hour. Judas hunting was more cost effective (5.4 ± 1.7 kills/hour) compared to blind hunting (3.2 ± 1.24 kills/hour). Adding the time of capture, the kill rate for Judas hunting reduced only slightly to 5.0 ±1.5 pigs/hour. We estimate that it required 7 hours of aerial hunting to kill eight of the Judas pigs and 31 untagged pigs, compared with 5 hours to kill 16 pigs during unaided aerial hunting.

Figure 3 shows a typical foraging pattern with unaided hunting becoming inefficient after approximately 250 minutes of flying time. However Judas pigs showed that additional time was still justified and could have been used to reduce the population even further. If Judas hunting had been continued there would have been an even greater contrast between the two methods.

5.5 Impact on pig population

The study block had a history (over the preceding few years) of a moderate level of pig control, conducted as part of Molesworth Station's ongoing pest management programmes. This included incidental killing of pigs during aerial hunting of goats, and poisoning and ground hunting of pigs. Station staff consider that this historical control had had a marked effect on pig density (J. Ward, Molesworth Station Manager, pers. comm). Despite that, our survey of the pigs from this area in 2004 (Project 80629) showed a very high prevalence of Tb (unpubl. data), as did the necropsy of the pigs killed in this trial, indicating that the historical control had had little effect on Tb levels.

The primary aim of the hunting effort expended in this trial was to further reduce pig densities, so that the effect of this on the prevalence of Tb in pigs could be measured as part of project R-80629. In total, about 93 pigs were removed from the area in the 5 months from late winter 2005. This includes some 20 pigs killed within the block by ground hunters just before this trial began (J. Ward, pers. comm.), and the 18 pigs shot incidentally during the Judas-capture phase. Although formal monitoring of the size of the reduction was not conducted because of the expense involved, there are subjective indications that it was substantial.

Pig densities in the block were clearly low. In the two days prior to the first Judas shoot, the same pilot (but a different shooter) spent approximately 4 hours flying time in the area and shot about 200 goats, yet only a single pig was seen (incidentally a Judas pig).

There were two marked pigs known to be present in the study area when the trial began. These were radio-tagged Marlborough Sounds sentinel pigs that had been released as part of project R-80629, but which had not been recovered as a result of transmitter or tag failure. Both of these were killed during the first two blind-hunting sessions.

As noted above, we estimate that during the capture phase at least 27 pigs could have been killed during about 4 hours flying time, a nominal unaided kill rate of almost 7 pigs/hour. In contrast, the final unaided kill rate during the hunting phase was only 2 pigs/hour.

Of the 20 pigs seen during unaided hunts (16 kills and four escapes) three were Judas pigs. A simple mark-recapture estimate (Lincoln index) would therefore suggest there was in the order of 60 pigs present during the hunting phase. This estimate will be biased low by the selective removal of unmarked pigs as the study progressed, but, conversely, biased high by the increasing tendency of marked pigs to hide from the helicopter.

These observations indicate that it is likely that the 93 pigs removed from this block after winter 2005 comprised a large proportion (probably well over half) of the pig population initially present, or at least of the component vulnerable to aerial hunting. In line with that, the pilot considered that at the end of the trial it was by far the lowest number of pig sightings

he had experienced in this area in 12 years of ground and aerial hunting there (P. Packham, Amuri Helicopters, Hanmer, pers. comm.).

5.6 Technical lessons

Some of the 'technological lessons" from this trial may be useful in subsequent Judas pig operations. The choice of helicopter, for example, had major cost implications. In this trial, we intended initially to use a lightweight low-cost Robinson R-22 helicopter, but were constrained by contractual arrangement to use of a larger, more expensive R-44 machine. However, we found the much greater hourly cost with the R-44 was at least partly offset by the ability of the machine to carry sufficient fuel for the entire day's hunting and recovery, so no time was wasted travelling to and from a fuel dump. Ferry time to and from the study area comprised about one-third of the total flying time used, and would have been an even larger component with the smaller, slower R-22 machine. The R-44 also provides a more stable platform for shooting and animal recovery, with greater safety margins of power (especially when working at altitude or in the heat). For these reasons (remote site, high altitude and animal recovery) the R-44 worked well for this trial. However, in general terms, if Judas pig work were to take place in more accessible terrain close to a fuel supply (or road), an R-22 machine would likely be more cost effective.

One frustrating aspect of the trial was our inability to re-locate all of the radio-tagged pigs during each hunt. This was normally due to being unable to receive a signal from the transmitter (rather than running out of time). For one of the pigs, the problem lay in the weakness of it transmitter signal – this was the only pig that had not been found and shot by the end of the final Judas hunt. For the others, we believe that the pilot's limited experience in radio-tracking may have played a role. On the two occasions we were able to fit dual (pilot and shooter) headsets to the telemetry receiver, eight of the nine Judas animals were re-located. The dual-headset system reduced pilot workload and increased shooter awareness of where the Judas animal was in relation to the helicopter.

None of the Judas animals lost their transmitters, previously a not uncommon fault with the ear-tag transmitters adapted for sentinel pig research by Sirtrack, N.Z. This improvement is presumed to be a result of using stainless steel (rather than plastic) pins in the ear-tag stem. There was some abrasion noted to the ears of several pigs where the metal pin contacted the skin.

6. Conclusions

This project was carried out mainly to reduce pig numbers for experimental purposes, and we consider that that was satisfactorily achieved. The trial did show greater hunting efficiency using the Judas technique (see Fig3), but the improvement was not as great as might have been expected given the 16-fold improvement in efficiency reported by Knowles (1994).

However, the efficiency gain in this trial is highly likely to be biased low for several reasons.

1. The unaided hunting was always conducted first. We did this because it was too costly (in terms of additional ferry and staff travel times) to conduct the unaided and Judas hunts on

separate days, and because disturbance caused by the first hour of hunting was considered far more likely to have an adverse effect on unaided hunting in the second hour than on Judas hunting. A consequence of this is that unaided hunting was always conducted earlier in the day than Judas hunting, and early-morning hunts are generally more successful than those conducted later in the day.

2. By trying to re-locate all nine Judas animals within a single hour we left little time to find pigs incidentally while travelling between Judas sites. In a fully operational setting, this time would be spent more productively by hunting more thoroughly while moving between sites.

3. Our inability to routinely re-locate all of the pigs will have markedly reduced the efficiency of the Judas technique.

We therefore consider that our results accurately represent the true kill rates for unaided hunting, but the kill rates for Judas hunting are likely to be biased low.

While Soule (1990) argues that the Judas method does not work particularly well for species such as feral pigs that are not strongly gregarious, this trial and McIlroy & Gifford (1997) and Knowles (1994) indicate that the technique has some merit. Female and young male pigs tend to live in stable social and family groups (McIlroy 2005). This trial provided little insight into how readily the Judas animals formed new associates once their original group had been eliminated because there appeared to be very few other survivors for them to associate with. Perhaps the main value of the tool in this trial was that it provided the opportunity to reliably eliminate whole family groups, particularly where such a group routinely frequented heavy cover. With unaided hunting, there was a high chance that some such family groups might escape their first encounter with aerial hunters and learn to hide from the helicopter, but with Judas hunting these wary survivors can usually be found and killed even when hiding.

Kill rates declined rapidly after the first two hunting sessions (the capture phase and first hunting session). This is likely to reflect a combination of lower pig density and increased active avoidance of the helicopter by survivors. The greatest strength of the Judas technique is perhaps that, by providing a way of aerially hunting pigs in dense cover, it minimises the effect of increased wariness on hunting success.

7. Recommendations

The Judas technique should be used for pig control and/or surveillance where pig density is low, and where tall (>2 m) vegetation cover is sufficiently patchy to enable most pigs to be forced into nearby open areas by the helicopter for shooting.

We recommend:

- Use of small helicopters (e.g. Robinson R-22) for accessible low-altitude areas, but larger machines in more remote, mountainous areas.
- Use of pilots with extensive radio-tracking experience wherever possible, or at least use of dual headsets so that the shooter can also assist with radio tracking.
- That the Judas pig technique is routinely used to complement ongoing pig-trapping programmes. The results did not indicate that females were much more effective than

males as Judas animal, or that breeding pigs were more effective than non-breeding pigs, so, in the interest of tagging efficiency, we recommend using all captured pigs where ongoing control is planned. Where eradication is the aim, however, it would seem advisable to use only neutered males so that if any transmitters fail the reproductive potential of the resulting untraceable animal (which is likely to be very difficult to kill using unaided hunting) is zero. Males are recommended here simply because they are easier to neuter in the field.

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