Manaaki Whenua
Landcare Research

Impact of aerial 1080 baiting with and without Epro deer repellent on a red deer and tahr population in Otago

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Impact of aerial 1080 baiting with and without Epro deer repellent on a red deer and tahr population in Otago

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Summary

Project and client

Manaaki Whenua – Landcare Research, Lincoln, was commissioned by OSPRI to assess the incidental impact on red deer (and also tahr) of an aerial 1080 baiting operation in Otago undertaken to help eradicate bovine tuberculosis (TB) from possums. The primary aim of the study was to determine the extent to which coating the 1080 bait with a proprietary deer repellent (Epro deer repellent; EDR) was successful in preventing significant incidental mortality of these two species. The work was undertaken between March and December 2018.

Objective

To determine the level and biological significance of non-target by-kill of red deer (and tahr) during an aerial 1080 TB possum control operation using EDR-coated and non-repellent cereal bait, by:

- using trail cameras placed in potentially high deer-use areas to compare camera visitation rates by red deer, possums, tahr and other species before and after 1080 baiting in two baited areas and a nearby unpoisoned area.

Methods

- A 6,825 ha TB-possum control in Timaru Creek, Otago, was split into two blocks: one poisoned with EDR-coated 1080 bait (EDR block; 45% of the poisoned area) and the other with non-repellent bait (No-EDR block; 55% of the poisoned area). Trail cameras were deployed in both blocks for 3 months before and 3 months after the 1080 baiting, and also in a nearby unpoisoned area (Dingle Burn; No-1080 block).
- Animal visits to camera sites were characterised by date, time, species, number of animals, and (where possible) age and sex. The number of visits and visitors and the duration of visits were used to compare changes in animal abundance before and after poisoning, taking into account the 'natural' (not related to 1080) changes in these indices in the No-EDR block. Over 4,200 visits and 5,300 visitors were recorded.

Results

- In the No-1080 block the number of deer visitors recorded over 3 months was 38.2% lower after the poisoning date than before. The decline in both poisoned blocks combined (93.4%) was significantly greater, indicating a 1080 by-kill effect. The decline in the No-EDR block (96.4%) was significantly larger than in the EDR blocks (77.4%), indicating an EDR effect.
- After adjusting for natural changes in activity, the deer by-kill estimates for the EDR block were 50.1–62.1% (depending on the assessment period) compared to 89.9–95.1% in the No-EDR block.
- EDR appeared to have best protected adult female deer, with by-kill estimates of 11.4–36.0% in the EDR block compared to 94.9–97.3% in the No-EDR block. Ten deer carcasses (all in the No-EDR area) were seen during camera recovery in September 2018, confirming that at least some deer had been killed. There was some delayed mortality, as an adult male found dead with 1080 residue was photographed alive 16

days after the poisoning date. Seventeen individually recognisable stags visited two or more camera sites, with the maximum distance between sightings being 7.2 km.

- Few tahr were recorded in the No-1080 block before the 1080 baiting, making it difficult to estimate overall tahr by-kill accurately. The 47% decline in tahr visitors in the No-1080 area did not differ significantly from the 61% decline in the poisoned areas combined. However, the decline in the EDR block (45%) was less than in the No-EDR block (80%), indicating an EDR effect (and therefore also a 1080 effect).
- In the No-1080 block possum visitor numbers declined naturally by 45%. Adjusted for that natural decline, the %kill estimates were modest for both the EDR block (87–95%) and the No-EDR block (84–88%). However, using visit duration as the measure of possum abundance, kill estimates increased to 85.7–98.6% and 85.6–93.9% for the EDR and No-EDR blocks, respectively. Further, excluding cameras within 500 m of the operational boundary, kill estimates were higher still (94.0–100.0%).

Conclusions

- The following conclusions are dependent on the assumption that there was little or no net movements of animals into or out of the study blocks, and that changes in animal activity in the unpoisoned area were matched by similar changes in the poisoned areas.
- We conclude that where deer repellent was not used, the by-kill of deer was high and affected all age–sex classes. Where EDR was used, it appears to have partially protected adult females. The operation will therefore have reduced current hunting opportunities greatly, especially for trophy stags, but will have had a lesser (but still substantial) effect on the reproductive capacity of the population.
- The evidence for tahr by-kill from this study is by itself somewhat inconclusive, but taken with evidence from the 1960s that tahr could be killed by aerial 1080 baiting, the results suggest some by-kill did occur, and, if so, that EDR reduced it.
- The aerial 1080 baiting operation successfully reduced possum activity to very low levels at camera sites more than 500 m from the boundary of the baited area in both the EDR and No-EDR blocks. There was an indication of delayed possum mortality in the zone just outside the baited area, and possibly also in the 500 m zone just inside it. The latter suggests that some possums at the margins of the baited area may have been ranging outside the baited area and so did not encounter bait immediately.

Recommendations

- If OSPRI wish to reduce deer by-kill in eastern Southern Alps beech forest habitats, some form of deer repellent should be used. Consideration should be given to testing whether use of 6–8 g 1080 baits rather than 12 g baits would enhance the effectiveness of the repellent in protecting deer, especially adult males.
- Given that recognisable stags were detected at locations up to 7 km apart, operations should either use only deer repellent bait, or at least the area in which repellent is used should be large (at least 10,000 ha).

1 Introduction

Manaaki Whenua – Landcare Research, Lincoln, was commissioned by OSPRI to assess the incidental impact on red deer (and also tahr) of an aerial 1080 baiting operation in Otago undertaken to help eradicate bovine tuberculosis (TB) from possums. The primary aim was to determine the extent to which coating the 1080 bait with a proprietary deer repellent (Epro deer repellent; EDR) was successful in preventing significant incidental mortality of these two species. The work was undertaken between March and December 2018.

2 Background

In forested mountain land aerial 1080 baiting is the most cost-effective approach to eradicating TB from possums and other wildlife (Warburton & Livingstone 2015). However, this method can sometimes cause high levels of incidental mortality ('by-kill') of deer (Nugent et al. 2001). In response to the resulting concern among hunters about the threat such by-kill poses to their hunting opportunities, Landcare Research was commissioned by Epro Limited in 2001 to identify a deer repellent that reduced the attractiveness of 1080 carrot bait to deer without also reducing its attractiveness to possums (Forsyth 2002). Subsequent field research has shown that Epro deer repellent (EDR) is effective in reducing incidental mortality in red deer with both carrot and cereal 1080 bait (Nugent et al. 2004, 2012, 2017; Morriss et al. 2006; Morriss 2007). However, using EDR adds substantially to the cost of aerial 1080 baiting, so it tends to be used mainly in areas where deer are highly valued by hunters and/or the landowners.

Despite being reduced to low levels historically, the red deer population in Otago remains a valued hunting resource and hunting demand is high. The Department of Conservation (DOC), for safety reasons, conducts a ballot for hunters wishing to hunt deer on the DOC estate during the roar period. The ballot allows one hunting party to have sole access to a block for a 7-day period. There are 50 blocks in the Wanaka area. These are available for 4 weeks, and in 2017 there were 700 applications for the 200 possible block hunting periods in the 2018 roar (P. Hondelink, DOC Wanaka, pers. comm., March 2018).

However, some of the area is part of a Vector Risk Area, and wildlife surveys in 2016 found one TB-infected ferret 5 km to the south of Timaru Creek and four TB-infected pigs within the catchment (Jennifer Lawn, OSPRI Dunedin, pers. comm., November 2018), so a programme of active management of possums (the primary wildlife host of TB) is required to achieve and confirm TB freedom for that area. As part of this, an aerial 1080 baiting operation was scheduled for the Timaru Creek area north of Wanaka in winter 2018.

There was elevated concern from hunters about the potential for a high by-kill of deer (and also tahr) during this planned operation, because in spring 2017 OSPRI used non-repellent 1080 bait for possum control in 60,000 ha of Molesworth Station. Subsequent monitoring by the New Zealand Deerstalkers Association (NZDA) and Manaaki Whenua – Landcare Research (MWLR) suggested this operation had caused an 87.6% reduction in red deer density (Morriss et al. 2018). In contrast, monitoring in parts of South Westland provided no evidence of any effect of aerial 1080 baiting (by DOC) on deer sighting rates when compared with unbaited areas nearby (Malham et al. submitted).

OSPRI therefore structured the Timaru Creek operation as a comparison of the effect of repellent and non-repellent cereal 1080 bait on red deer by-kill, and commissioned MWLR to independently monitor the outcomes using trail cameras to assess changes in deer activity. The use of trail cameras also enabled incidental monitoring of the effect of the two different baiting treatments on possums, and, for the first time, on tahr.

3 Objective

To determine the level and biological significance of non-target by-kill of red deer (and tahr) during an aerial 1080 TB possum control operation using EDR-coated and non-repellent cereal bait, by:

- using trail cameras placed in potentially high deer use areas to compare camera visitation rates by red deer, possums, tahr and other species before and after 1080 baiting in two baited areas and in a nearby unpoisoned area.

4 Methods

4.1 Trial design and study area

4.1.1 Trial design

We used a before-after/treatment-non-treatment trial design, with two treatments (repellent and non-repellent 1080 cereal baiting).

Initial planning included discussions with local helicopter pilots who carried out wild animal recovery operations (WAROs), and Paul Hondelink (DOC, Wanaka) who had several decades of WAROs and aerial tahr control experience in the Timaru Creek area. In January 2018 we visited the field site to assess the feasibility of using different ungulate monitoring methods, including trail cameras, ground-based observers, and systematic carcass searches. It was decided that trail camera monitoring was the most practical technique for monitoring both deer and tahr in this habitat.

We assessed changes in the relative abundance of red deer, tahr, possums and other species by determining camera visit rates over 3 months before and 3 months after the date on which 1080 baiting was conducted. Because the camera visit rate is influenced not only by changes in deer abundance but also by large seasonal changes in overall deer activity levels, as well as the potential for avoidance of camera sites as a result of humans visiting or even deer shying away from the cameras themselves, the design included monitoring deer sighting rates in a non-treatment (i.e. unpoisoned) 'No-1080' area.

Previous deer by-kill monitoring trials have included systematic carcass searches (Morriss et al. 2006; Morriss & Nugent 2008; Nugent et al. 2012; Morriss & Nugent 2017) in which an estimate of search efficiency (and therefore of deer carcass density) is derived by first deploying and then searching for a known number of deer-sized objects (paper sacks imitating deer carcasses). It was decided that the likely patchy distribution and estimated overall lower density of deer in Timaru Creek (in comparison to areas previously assessed) would preclude worthwhile carcass searches, so these were not included in the trial design. Nevertheless, when cameras were deployed and retrieved, the numbers of live and dead deer seen were recorded.

4.1.2 Study area

The TB-possum control operation comprised 6,825 ha in Tīmaru Creek, Otago, of which 3,120 ha (45%) was treated with EDR-coated 1080 bait (EDR block), with the remaining 55% treated with non-repellent 1080 bait (No-EDR block; Figure 1). The area is predominantly beech forest surrounded by extensive alpine grassland, with the lower reaches dominated by mānuka and sweet briar. Parts of the catchment and adjoining DOC land to the north are subjected to commercial red deer hunting from helicopters, excluding some adjoining private and leasehold land. DOC also conducts aerial shooting of tahr, targeting females to minimise the southward expansion of the tahr breeding range.

The Dingle Burn catchment to the north (Figure 1) was chosen as the non-treatment area (No-1080 block), as habitat, deer densities and deer movement patterns there were expected to be like those in Timaru Creek. Neither Timaru Creek nor the Dingle Burn had previously been subjected to aerial 1080 baiting.

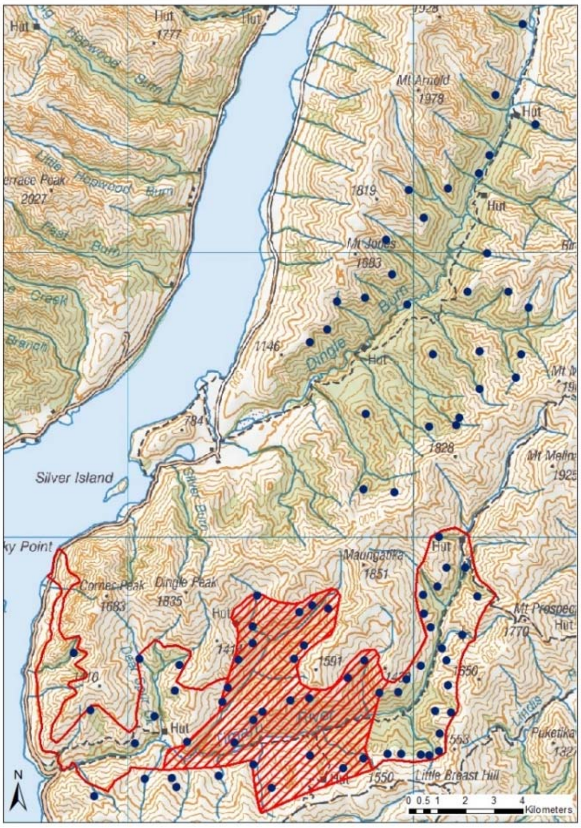

Figure 1. Location of trail cameras (blue dots) deployed in Timaru Creek and the Dingle Burn, Otago, March–September 2018. The red line shows the overall possum control operation boundary, with the cross-hatched central portion poisoned with Epro deer repellent-coated cereal bait (EDR). Surrounding areas within the red line were poisoned with non-repellent 1080 bait (No-EDR). Five cameras deployed in the SW corner ended up being outside the operational area following changes to the operational boundary between camera deployment and consequent baiting.

4.1.3 Baiting operation

The Timaru Creek baiting operation was carried out by Central South Island Helicopters Ltd. The EDR and No-EDR were pre-fed once with 16 mm (6–8 g) cereal RS5 repellent and non-repellent baits, respectively. Prefeed was broadcast at 1.0 kg/ha on 28–29 May 2018 along flight paths 220 m apart. Toxic 1080 bait (20 mm 12 g cereal baits) were broadcast at 2 kg/ha 23 days later on 20–21 June 2018 using the same flightpath spacing. There were three or four fine nights before 16.0 mm of precipitation was recorded on 25 June. A total of 86.9 mm of precipitation was recorded in July 2018 following toxic baiting.

4.2 Assessment of outcomes

4.2.1 Camera trapping

Over 17–18 March 2018, 90 trail cameras (22 Reconyx PC900, 27 Reconyx XR6, 26 Bushnell Aggressor and 15 Bushnell Trophy Cam) were deployed, either in clearings or along the bush edge where game trails were obvious (i.e. high-animal-use sites; Figure 2). Staff deployed cameras using a helicopter for rapid access and coverage of the large area monitored. Twenty-two cameras were arrayed in the EDR-1080 area, 33 in the standard 1080 area, and 30 in the No-1080 area (Dingle Burn).

Figure 2. A pole-mounted trail camera located to photograph ungulates on a game trail along a spur above the bush edge, deployed in Timaru Creek, Otago, March–September 2018.

At the camera locations in Figure 1 cameras were positioned to monitor game trails or open areas, avoiding areas of thick undergrowth or steep topography. Cameras were secured to trees or iron poles at c. 1.5 m above the ground and pointed slightly downward but with at least 10 m visibility (Figure 2). Cameras were left in place for about 6 months One camera was stolen, some were poorly positioned or were knocked off-line or opened by possums, and some suffered technical failure.

In total, 199,578 photos were recorded, but three-quarters of these were not analysed because they were non-animal photos (false triggering due to the harsh alpine environment, where contrast in temperature and moving tussock caused cameras to trigger) or were taken by cameras that didn't remain functioning for all or most of the whole 6-month period. In total, we used 53,831 photos from 68 cameras, of which 38% were of deer, 21% of possum, and 4% of tahr.

4.3 Data analyses

The animal visits recorded by trail cameras were characterised by location, treatment, date, time, species, number and (where possible) age and sex class, and the data were used to derive various indices of animal activity that were assumed to provide measures of relative abundance. For each species, the number of visits and visitors was determined by classifying any images separated by more than 5 minutes from any other image of that species as separate visits and counting the number of different animals observed within each visit.

Trends over time in the total number of visits and visitors were compared between the EDR, No-EDR and No-1080 areas for various time periods. For possums, the summed duration of visits (in minutes) was used as an alternative index of activity. The study period spanned 3 months before the poisoning date of 20 June 2018 and 3 months after. Activity measures (visit numbers, visitor numbers, and (for possums) the summed visit duration were calculated for each 30-day period within the study period.

The change in visitor numbers between the three periods before and after the poisoning date was compared using contingency tables in a two-stage approach: first, the change between poisoned and unpoisoned areas was compared to check for an overall poisoning effect, and then the difference between the EDR and No-EDR blocks was compared to check for a repellent effect.

In the No-1080 block there were substantial changes in animal activity before and after poisoning that were clearly unrelated to the 1080 operation. The data from that block were therefore used to convert the recorded changes in activity into estimated %kill (possums) or by-kill (other species). For this, the trends in activity were plotted by month relative to the poisoning date, and for the No-1080 area various trend lines were fitted to the data. The trend line that best fitted the observed data (usually a second-order polynomial, but linear or exponential models in some instances) was then used to predict the expected activity level for each monthly period. The changes in those expected levels were then used to calculate the likely magnitude of the natural non-1080 changes in activity. For this, the post-poisoning activity index for a given assessment period was expressed as percentage of the index of the equivalent period before that date. That percentage was then used to rescale the pre-poisoning activity indices from the two poisoned blocks. Three assessment periods were compared: the periods 1, 2, and 3 months before and after the poison date.

We emphasise that this adjustment is crucially dependent on the assumption that 'natural' (unrelated to 1080) changes in animal activity in the poisoned blocks would have been the same as the natural changes in the No-EDR block. In this context, natural changes include the effects of recreational and commercial hunting, and (for tahr) DOC culling. Intuitively the 1-month comparisons are likely to be the most accurate in that the populations will have had less time to be affected by potential differences between the blocks in animal behaviour and mortality rates. However, the number of observations is obviously much larger for the 3-month periods and therefore more statistically powerful.

Multiple visits could be recorded by individual deer and the same individual could also be photographed by different cameras. For example, one readily identifiable six-point stag with a damaged left brow tine was photographed on four different cameras up to 7.2 km apart over a 2.5-month period (Figure 3).

Figure 3. A distinctive six-point stag photographed on four different cameras in the lower Dingle Burn, 14 April to 29 June 2018. Note the slightly damaged left brow tine.

There was no unpoisoned buffer between the EDR and No-EDR blocks in Timaru Creek, so animals photographed on the cameras near the boundaries between treatments could have had access to either bait type. For deer and tahr (but not possum) analyses, cameras within 1 km of the boundary between the two treatments were therefore excluded from some analyses.

5 Results

5.1 Species recorded

In total, for the main deer and tahr analyses there were 4,258 visits by 5,310 visitors over 184 days (Table 1). This included 13 mammal species (including humans), with possums, deer, hares, sheep and tahr the most common visitors (Table 1).

In the 92-day pre-1080 period possum abundance was broadly similar in the EDR, No-EDR, and No-1080 blocks, as judged by mean visitors per camera (30.2, 20.6, and 31.3, respectively). The equivalent figures for deer (8.9, 28.8, and 12.3, respectively) suggested deer were most abundant in the No-EDR block, while those for tahr (5.4, 2.8, and 0.6 respectively) suggest there were far fewer tahr in the No-1080 block than in the two 1080 blocks.

The detection rates for smaller mammals and birds were probably biased low because cameras were set up to photograph larger species and were sub-optimal for photographing smaller species. Nonetheless, there were 131 bird visitors, mostly (81%) blackbirds and thrushes. Of the few (13) native bird visitors photographed, tomtits were the most common. Only one kea visit was recorded, in the Dingle Burn in August.

Table 1. Number of visitors recorded over 92 days before (pre) and 92 days after (post) 21 June 2018, the date on which toxic bait was sown in the EDR and No-EDR blocks. These data are based on 17 cameras in the EDR block, 24 in the No-EDR block, 24 in the No-1080 block and two outside the poisoned area in the SW corner of Timaru Creek.

	EDR		**No EDR**		**No 1080**		
Visitor	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Total**
Possum	467	46	507	44	750	414	2,228
Deer	190	32	711	24	296	183	1,436
Hare	35	53	196	191	133	123	731
Pig	84	14	140	26			264
Tahr	105	44	64	13	15	8	249
Sheep			248				248
Rabbit	80	50	5		1	1	137
Cat	16	4	24	11	39	15	109
Blackbird	1		73	24			98
Chamois	2	1	11	5	30	22	71
Hedgehog			9	2	2		13
Human	8	1	14				14
Thrush			1	11			12
Tomtit	5	2	2	1	2		12
Magpie			1	4			5
Stoat	1		1		1		3
Ferret			2		1		3
Other bird			2	1			3
Kea						1	1
Redpoll	1						1
All	**995**	**247**	**2,012**	**357**	**1,270**	**767**	**5,648**

5.2 Changes in visit rates

5.2.1 Natural 'non-1080' changes

For deer, tahr and possums, visit rates in the No-1080 block generally declined over the 6-month period we monitored, although tahr activity increased again in the final month of the study (Figure 4). This is assumed to reflect decreased activity levels in winter and/or higher than usual activity levels in the mating period in autumn/early winter for possums, deer and tahr.

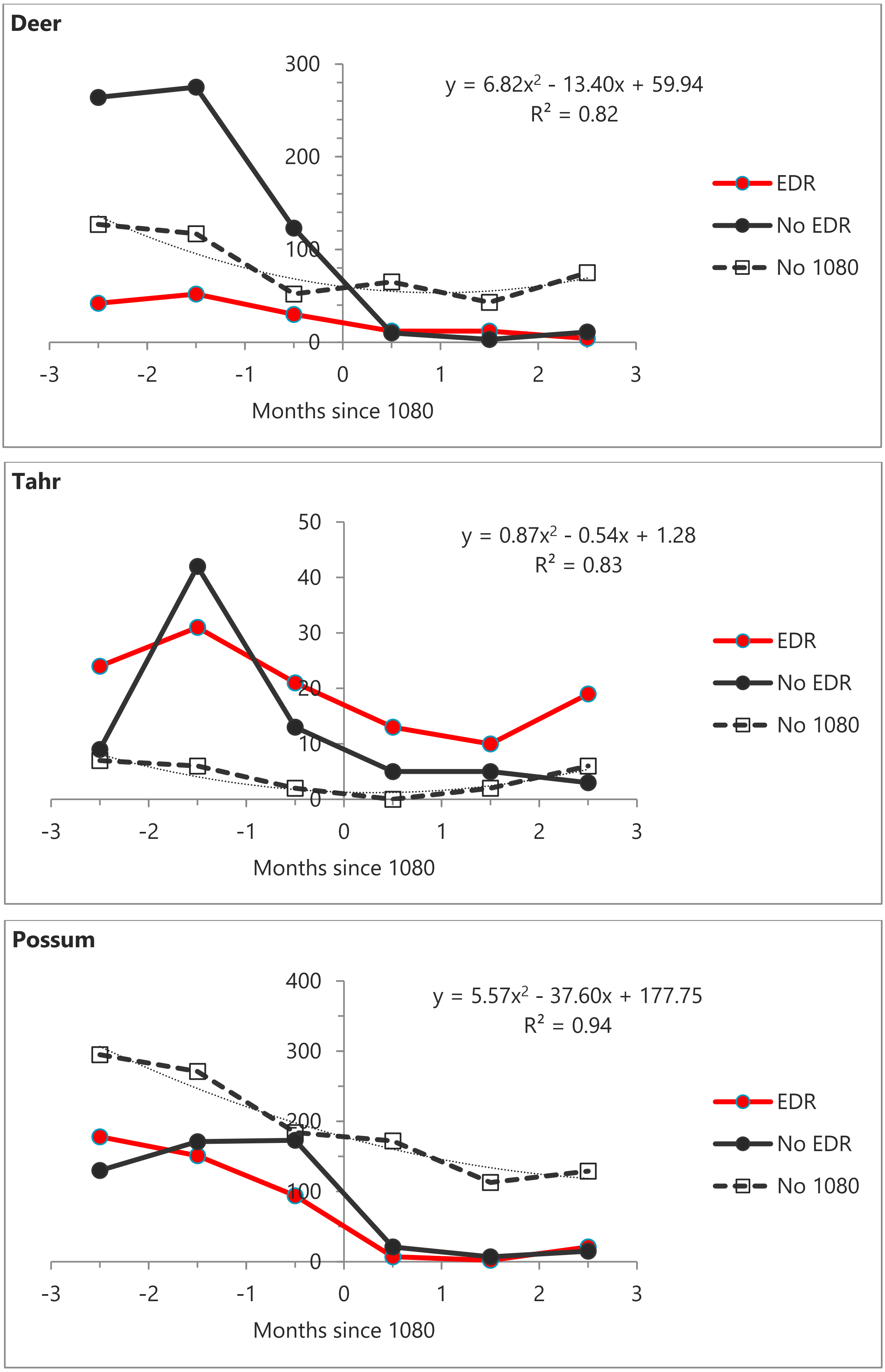

Figure 4. Trends in the total number of deer, tahr and possum visitors recorded at trail camera sites in Timaru Creek and the Dingle Burn, winter 2018. The treatments were two aerial 1080-baited blocks sown with either Epro deer repellent bait (EDR) or bait without repellent (No EDR) in Timaru Creek, and one not poisoned (No 1080) in the Dingle Burn. The time intervals are the number of months before or after the dates on which the 1080 bait was sown (20–21 June 2018). The curves (faint dotted lines) for the No-1080 treatment were used to smooth between-period variation in the data (see methods).

5.2.2 Deer by-kill

Ten deer carcasses (all in the No-EDR area) were seen during helicopter-based camera recovery in September 2018, with seven seen from the helicopter and three observed at or near camera sites, indicating that at least some deer had been killed. No live deer were seen in either the poisoned or unpoisoned areas during camera recovery compared to 19 deer seen when cameras were deployed (17 seen in the No EDR 1080 area and two near the EDR area).

In the unpoisoned No-1080 block, the number of deer visitors recorded over 3 months after the poison date was 38.2% lower than before (Figure 4 & Table 2). For both poisoned blocks combined, the decline in number of deer visitors (93.4%; 786 vs 52) was significantly greater than in the No-1080 block (Pearson χ^2 212.8, $P < 0.001$), indicating a major 1080 effect. All major age–sex classes were affected, with the greater declines in visitor numbers in the poisoned areas relative to the No-1080 block (Figure 5 & Table 2) being statistically significant for adult males (95.5% vs 42%; $\chi^2 = 53.4$, $P < 0.001$), adult females (92.0% vs 31.6%; $\chi^2 = 66.2$, $P < 0.001$) and all younger deer combined (95.2% vs 43.2%; $\chi^2 = 84.1$, $P < 0.001$).

Within the poisoned areas, the decline in the total number of deer visitors in the EDR block was significantly lower than in the No-EDR block (77.4% vs 96.4%, Table 2; $\chi^2 = 47.6$, $P < 0.001$), indicating a lesser overall reduction in the repellent block. However, there was no indication that EDR protected adult males, as no stags were photographed in the EDR block after poisoning (Figure 5a), and the difference in total adult male visitors between the EDR and No-EDR blocks (Table 2) was not significant (Fisher's Exact Test, $P = 0.61$). For adult females, and for all young deer combined, however, there were significantly smaller reductions in the EDR block than in the no-EDR block (Figure 5b, c & Table 2; Fisher's Exact Test, $P < 0.001$ and Fisher's Exact Test, $P < 0.001$ respectively), indicating some level of protection.

The estimated overall deer by-kill in the No-EDR block was high (89.9–95.1%) regardless of the assessment period used, whereas the estimated overall 1080 by-kill in the EDR block was substantially lower (50.1–62.1%), and lowest for adult females (11.4–36%) (Table 2).

There were some indications that by-kill increased over time, most notably for adult males in the No EDR block and adult females in the EDR block. Supporting that possibility, we recorded one clear example of delayed mortality; one stag with distinctive antlers was last photographed alive 16 days after the 1080 baiting (Figure 6) but was subsequently found dead with 1080 residue (0.52 mg/kg) beside the camera where it was last photographed.

Some stags had distinctive antlers that enabled them to be identified as the same animal if they were photographed on multiple occasions. Most were only identified once or at only one camera site, but 17 were identified visiting two to four camera sites. For these 17 stags, the average maximum distance between camera sites at which they were recorded was 3.3 km, with the greatest distance between sightings of the same animal being 7.2 km.

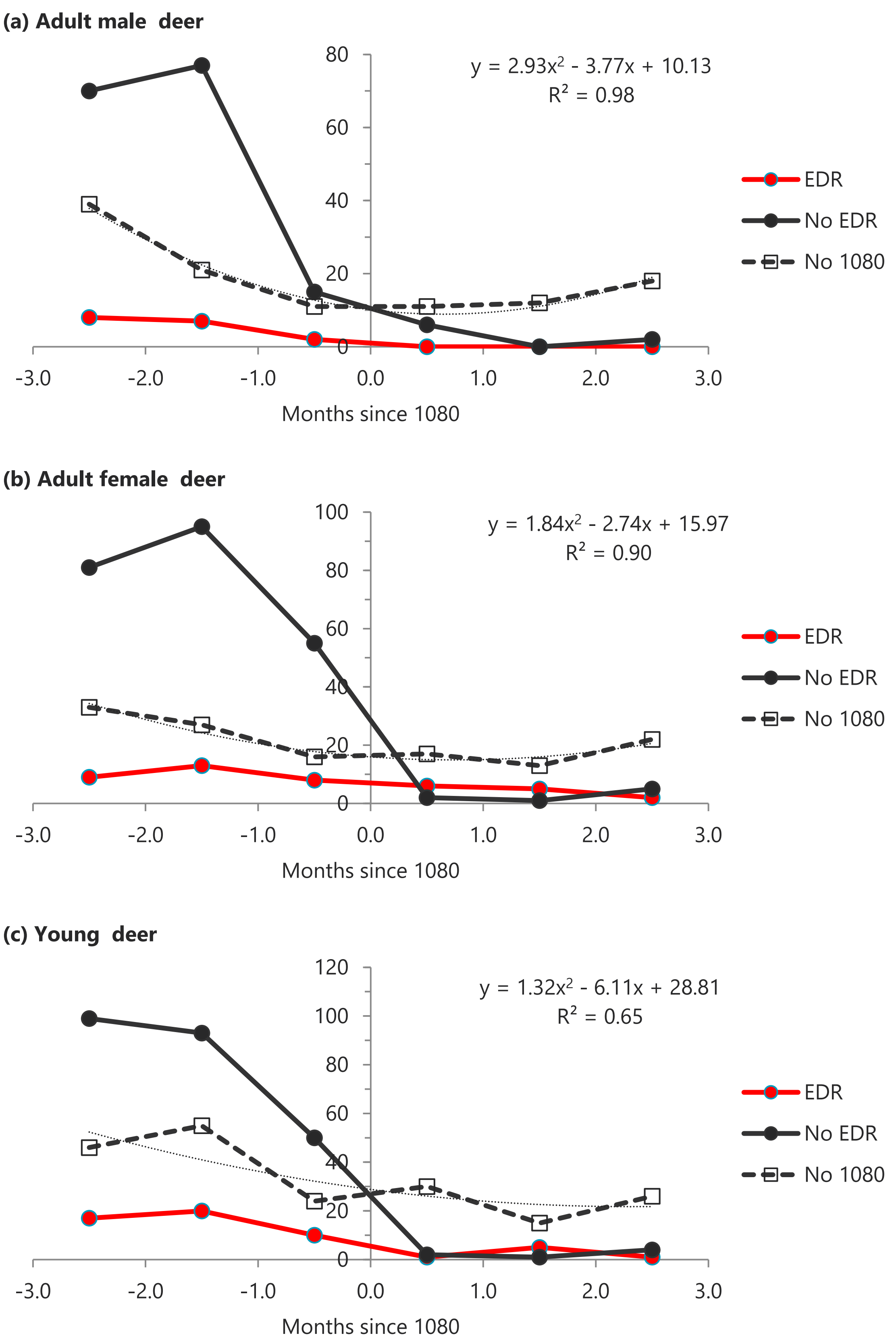

Figure 5. Trends in the monthly total number of deer visitors (y axes) recorded at cameras sites in blocks aerially poisoned with either repellent (EDR) or non-repellent cereal 1080 bait (No EDR), or not poisoned (No 1080), by sex–age class (adult males >2 years of age, adult females >2 years of age, and all young deer <2 years of age. The curves (faint dotted lines) for the No-1080 treatment were used to smooth between-period variation in the data (see methods).

Figure 6. A distinctive 16-point red stag that was photographed at two different camera sites 0.8 km apart in the No EDR block. It was photographed alive 16 days after the poison date, but then found dead with 1080 residue (0.52 mg/kg) in September 2018.

Table 2. Numbers of deer visitors, overall and by major sex–age class, recorded by trail cameras deployed for 6 months in Timaru Creek (EDR and No EDR 1080 baited) and the Dingle Burn (No 1080), Otago, March–September 2018. Estimates of the reduction in animal abundance attributable to the 1080 poisoning (%kill) were derived by factoring in the reductions in activity observed in the unpoisoned area. Three %kill estimates were derived by comparing the periods 1, 2, and 3 months before and after poisoning. Cameras within 1 km of the EDR/No EDR boundaries are excluded

	Total no. of deer visitors		Estimated %kill		
	3 months pre-poison	3 months post-poison	1 month pre/post	2 month pre/post	3 months pre/post
Overall					
No 1080	296	183			
EDR	124	28	50.1%	56.4%	62.1%
No EDR	662	24	89.9%	95.1%	93.9%
Adult males					
No 1080	71	41			
EDR	17	0	100%	100%	100%
No EDR	162	8	36.2%	86.2%	88.5%
Adult females					
No 1080	76	52			
EDR	30	13	11.4%	29.1%	36.0%
No EDR	231	8	95.7%	97.3%	94.9%
Young deer					
No 1080	125	71			
EDR	47	7	87.7%	70.0%	73.5%
No EDR	242	7	95.1%	96.8%	94.9%

5.2.3 Tahr by-kill

Few tahr were photographed in the No-1080 block (Figure 4). The 47% decline in tahr visitors in the No-1080 area did not differ significantly from the 61% decline in the poisoned areas combined (Table 3; $\chi^2 = 0.36$, $P = 0.55$). However, the 45% decline in the EDR block was significantly smaller than the 80% decline in the No-EDR block ($\chi^2 = 8.9$, $P = 0.003$), and the %kill estimates were therefore lower where repellent was used compared to where it was not used (11–30% vs 44–71%; Table 3).

The unadjusted reductions in tahr visitor numbers between the 3 months before and 3 months after the 1080 baiting suggest all age–sex classes were less affected by 1080 in the EDR blocks than in the No-EDR block, with adult males and juveniles possibly more affected (45% vs 93% reductions, respectively, and 31% vs 96% reductions, respectively) than adult females (18% vs 87%).

Table 3. Total numbers of tahr and possum visitors recorded by trail cameras deployed for 6 months in Timaru Creek (poisoned) and the Dingle Burn (unpoisoned), Otago, March–September 2018, derived by comparing the periods 1, 2, and 3 months before and after poisoning. Cameras within 1 km of the EDR/No-EDR boundaries are excluded from the tahr analysis but not from the possum analysis

	Total no. of visitors			Estimated %kill	
	3 months pre-poison	3 months post-poison	1 month pre/post	2 month pre/post	3 months pre/post
Tahr					
No 1080	15	8			
EDR	76	42	10.7%	29.6%	14.9%
No EDR	64	13	44.5%	71.0%	68.7%
Possum					
No 1080	750	414			
EDR	441	31	90.9%	94.4%	87.3%
No EDR	508	44	85.0%	87.7%	83.5%

5.2.4 Possum kill

In the No-1080 block, possum visitor numbers recorded on all cameras inside the baited areas declined steadily throughout the study (Figure 4), with total visitors in the post-poison period 45% lower than in the pre-poison period (Table 3). The much higher (92%) overall decline in the poisoned areas combined was significant (χ^2 = 218.6, P < 0.001). The slightly larger reduction (93%) in total visitors recorded in the EDR block was not significantly different from the 91% reduction in the No-EDR block (χ^2 = 3.0, P = 0.08). Adjusted for natural decline, the %kill estimates were modest (by modern standards) for both the EDR block (87–95%) and the No-EDR block (84–88%) (Table 3). However, these estimates are likely to understate actual kill, for two reasons.

Firstly, the average duration of visits by possums within the poisoned areas decreased substantially after the 1080 baiting (Figure 7a). Before the 1080 baiting date the average duration of possum visits was similar in the poisoned and unpoisoned areas (0.41 ± 0.11 minutes vs 0.38 ± 0.10 minutes [95% CL], respectively) but after that date the average duration was significantly lower in the poisoned area (0.18 ± 0.13 minutes vs 0.42 ± 0.15 minutes, respectively; *t*-test [unequal variances], P = 0.02). Based on the change in the total duration of possum visits to camera sites (Figure 7b) and adjusting for the change in the No-1080 block resulted in 1-, 2-, and 3-month 1080-kill estimates of 98.1%, 98.6%, and 85.7%, respectively, in the EDR block and 85.6%, 93.9%, and 90.5%, respectively, for the No-EDR block.

Secondly, many of the cameras in Timaru Creek were close to or on the edge of the baited area. Including all cameras in Timaru Creek, and grouping them into four distance-to-poison-edge classes (Figure 7c) indicated a 94.0–100.0% reduction in the total duration of possum visits to cameras more than 500 m inside the baited area, but smaller reductions for cameras closer to or outside the baited area. Most notably, the reductions in possum activity were greater when assessed over 2 or 3 months than when assessed over the 1-month periods immediately before and after the 1080 baiting.

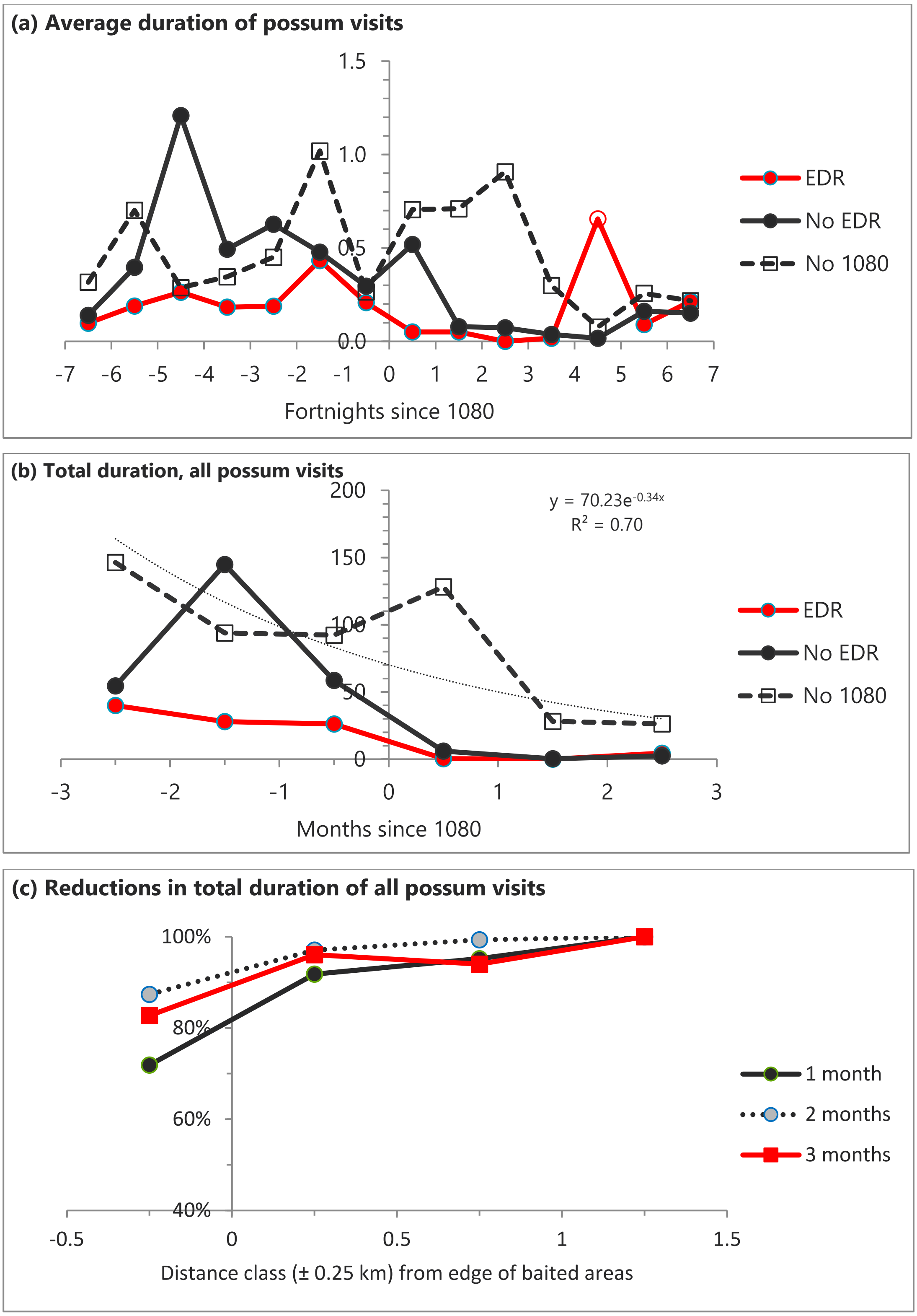

Figure 7. Changes in the duration (in minutes) of possum visits to camera sites in blocks aerially poisoned with either repellent (EDR) or non-repellent cereal 1080 bait (No EDR) or not poisoned (No 1080), showing (a) variation in the average duration of individual visits, by fortnight, separately for each block; (b) variation in the total duration of possum visits, by month, by block; and (c) the percentage reductions in the total duration of possum visits in the two poisoned blocks combined, for 1-, 2-, and 3-month assessment periods in relation to the edge of the baited areas. Note that in (a) there is only one possum visit during the fifth fortnight after poisoning. The curve (faint dotted line) in (b) for the No-1080 treatment was used to smooth between-period variation in the data (see methods).

5.2.5 Impacts on other species

Cats were recorded in all blocks, with the number of visitors in the No-1080 block again declining sharply into winter (Figure 8). There was no significant difference in the overall decline between poisoned and unpoisoned areas ($\chi^2 = 0.1$, $P = 0.75$), nor between the two poisoned blocks (Fisher's Exact Test, $P = 0.14$).

Chamois were not recorded in the EDR block (Figure 8), and there was no significant difference in the decline between the No-EDR and the unpoisoned area ($\chi^2 = 0.6$, $P = 0.43$).

Pigs were recorded only in the two poisoned blocks (Figure 8), so no correction for natural changes in pig activity was possible. The number of pig visitors was 73–87% lower after 1080 baiting (depending on block and assessment period). There was no significant difference in the decline between the EDR and No-EDR blocks ($\chi^2 = 0.3$, $P = 0.57$).

There was no indication of any 1080 by-kill for hares, as their numbers were as high or higher after baiting compared to before (Table 1). Almost all rabbits were recorded in the EDR block, where their counts declined by 50% after baiting (Table 1), which might be a 1080 effect or simply a seasonal decline in activity. Similarly, the number of blackbirds in the No-EDR block reduced by 66% (Table 1). Again, that might have been a seasonal effect, but the decline was high enough to suggest there was some 1080 by-kill of this species, as has been reported in a number of operations previously (Morriss et al. 2016).

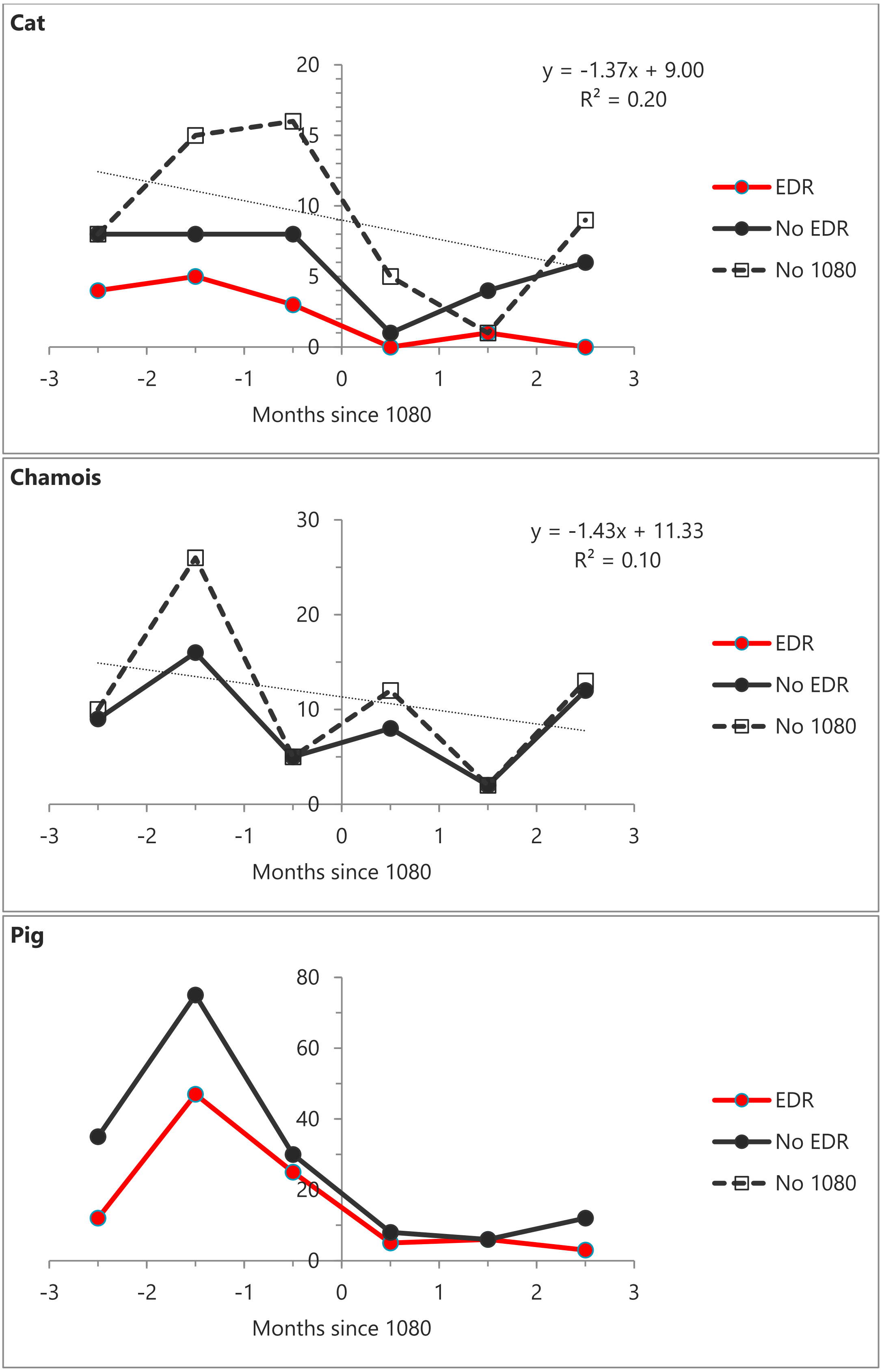

Figure 8. Trends in the total number of visitors to trail cameras sites in two aerially 1080 baited areas, either with Epro deer repellent bait (EDR) or without repellent bait (No EDR), and in one area not poisoned (No 1080), for cats, chamois and pigs. The faint dotted lines for cats and chamois represent best-fitting models for the No 1080 trend data that were used to estimate %by-kill (see methods).

6 Discussion

6.1 Control effectiveness and by-kill

The possum control operation in Timaru Creek appears to have successfully reduced possum numbers to very low levels, at least as judged by the changes in the total amounts of time possums spent within the camera detection zones, and at least in areas more than 0.5 km inside the baited area. There is some indication that possums just outside the baited areas were not killed until some weeks after baiting, as the % reduction in activity was larger when assessed over a 2-month period rather than with a 1-month period.

The sighting of 10 dead deer (all in the No-EDR block and the only one analysed containing 1080 residue) leaves no doubt that some deer were killed, and the estimated overall by-kill exceeded 90% in the No-EDR areas. The use of EDR bait reduced by-kill significantly, but the overall by-kill in the EDR block still exceeded 50%. The magnitude of these estimates obviously depends on the underpinning assumption that the seasonal- or hunting-related changes in deer visiting rates in the No-1080 block were matched by similar changes in the poisoned areas. There is no way of independently verifying this assumption, so we suggest that estimates be treated as relative indices of kill rather than absolute measures.

In the No-EDR block, reductions in excess of 90% for adult females and young deer were recorded within 1 month of the 1080 baiting, whereas for adult stags the estimated by-kill was initially (in the first month) moderate (36%) but then increased to 86–88% in subsequent months (Table 2). The initial outcome of apparently lower mortality of adult stags matched a similar pattern inferred for the 2017 Molesworth operation, in which proportionally many more large-bodied stags were seen after poisoning than in an unpoisoned area nearby (Morriss et al. 2018). The apparent increase in adult male kill over time at least partly reflected delayed mortality, as was unequivocally observed for one clearly recognisable stag. Compared to the Molesworth outcome, the higher kill of adult males (based on the 3-month assessment period) could plausibly reflect use of larger baits (12 g vs 6 g) and/or stags possibly being hungrier in Timaru Creek in winter (immediately after the rut) than in spring on Molesworth.

In the EDR block there were too few adult males present before 1080 baiting to accurately assess by-kill, but young deer were partially protected by the repellent and adult females even more so. Given the relatively low by-kill of adult females, the 1080 operation had only moderate effect on the reproductive potential of the population within the EDR block. We hypothesise that the lesser survival of young deer reflects smaller body size and possibly less cautious feeding than adult females, making it more likely for them to find a lethal quantity of bait before the onset of 1080 toxicosis.

The reasons for the higher-than-usual by-kill of deer (with or without EDR) are not known but could be a consequence of there being few other alternative winter foods in the simple beech forest that covers most of the area, and/or the open understorey in that forest type enabling all deer to quickly find enough baits to kill them.

No dead tahr were seen during camera recovery, and the reductions in tahr visitor numbers were similar in the poisoned and unpoisoned areas, implying that the 1080 operation had little effect on tahr. However, there did appear to have been a reduction in the number of tahr visitors in the No-EDR block relative to the EDR block. The difference could reflect differences in the reductions caused by culling of female and young tahr by DOC, but most of the observed difference was a difference in adult male visitors. Assuming that DOC culling effects were similar in those two areas, our results would suggest that some by-kill did occur, and, further, that EDR reduced the by-kill.

The number of other species photographed was typically too low to provide enough statistical power to detect anything other than a very high by-kill, and this was often exacerbated by few or no animals being recorded in the No-1080 block.

There was no indication of a substantial effect of 1080 baiting on chamois numbers, with more visitors recorded in the first month after baiting than in the month before. For cats, only a single cat was recorded in the EDR block after the baiting compared to 12 before, suggesting by-kill there, but the sample size was too small to indicate whether or not the apparent effect was likely to be real. For pigs, numbers were much lower after baiting, suggesting at least some by-kill. If so, there was no evidence of any difference between the EDR and No-EDR blocks.

6.2 Non-random trail-camera monitoring of 1080 kill

We consider that the monitoring design used in this study was successful. Placement of the cameras at the most easily accessible (by helicopter) site with signs of high deer use allowed us to record a far larger number of visits than would have been achieved with random placement within forest. However, the large changes in activity recorded in the No-1080 block for many species emphasise the need for the design to always include a non-treatment area that is as far as possible identical to the treatment areas.

We note that the design for the trial was sub-optimal in that the EDR block was sandwiched between and contiguous with two No EDR blocks. That makes it likely that many deer would have had ranges overlapping both treatments, which would have resulted in deer finding and consuming non-repellent bait, and possibly thus learning that cereal bait is edible regardless of what it looks and smells like.

6.3 Conclusions

In summary, the aerial 1080 baiting operation successfully reduced possum activity to very low levels at camera sites more than 500 m from the upper edge of the baited area. There was an indication of delayed possum mortality in the zone just outside the baited area, and possibly also in the 500 m zone just inside it. The latter suggests the hypothesis that some possums at the upper margins of the baited area may have been ranging outside the baited area, and so did not immediately encounter bait.

The results suggest that other than the adult females within the EDR block, most deer in the baited area were killed. Young deer were partially protected by the repellent but less so than for adult females. The operation will therefore have greatly reduced current hunting opportunities, especially for trophy stags, but will have had a smaller (but still substantial) effect on the reproductive capacity of the population.

The evidence for tahr by-kill from this study is by itself somewhat inconclusive, but taken with evidence from the 1960s that tahr could be killed by aerial 1080 baiting (albeit with carrot bait; Douglas 1967) we suggest some by-kill did occur, and, if so, that EDR reduced it.

7 Recommendations

- If OSPRI wish to minimise deer by-kill in eastern Southern Alps beech forest habitat, some form of deer repellent should be used. Consideration should be given to testing whether use of 6–8 g 1080 baits rather 12 g baits would enhance the effectiveness of the repellent in protecting deer, especially adult males.
- Given that recognisable stags were detected at locations up to 7 km apart, operations should either use only deer repellent bait, or the area in which repellent is used should be large (at least 10,000 ha).

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