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The propensity of spotted-tailed quolls (*Dasyurus maculatus*) to encounter and consume non-toxic meat baits in a simulated canid-control program

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Abstract. Using a biomarker, we assessed the propensity of spotted-tailed quolls (*Dasyurus maculatus*) to encounter and consume non-toxic meat baits, ordinarily laced with the poison 1080 (sodium monofluoroacetate) and deployed for control of wild dogs (*Canis lupus dingo*, *Canis familiaris* and hybrids of the two) in southern Australia. In the first experiment, 60 unpoisoned meat baits injected with Rhodamine B were placed on the surface of the ground at 250-m intervals along two separate transects crossing an open woodland study area. One week after placement, a range of animals, including quolls, had removed all baits. Microscopic assay of whisker samples collected from live-captured quolls later revealed that 6 of 10 (60%) animals were positive for the biomarker, indicating that they had encountered and consumed baits. In the second experiment, conducted at the same site one year later, 150 similarly prepared meat baits were delivered aerially from a helicopter along the same transects, at a rate of one bait every 100 m. Eight of 17 quolls (47%) were found to have encountered and consumed at least one and up to five baits. Combined with previous studies, our results reaffirm that surface or aerial baiting operations for wild dogs may place local quoll populations at risk. However, further research is necessary to establish the relationship between this risk and actual mortality levels during such baiting operations since there are a number of factors that may influence the toxicity of baits for spotted-tailed quolls in a field situation as well as the danger those baits may pose.

Introduction

At the interface between public forested land and private agricultural land, free-ranging wild dogs (*Canis lupus dingo*, *Canis familiaris* and hybrids of the two) have often been implicated in the killing and maiming of domestic stock, particularly sheep (*Ovis aries*) (McIlroy *et al*. 1986; Fleming and Korn 1989). A number of control techniques for dogs are used in an attempt to reduce the frequency of these events, including electric fencing, trapping and baiting with 1080 poison (sodium monofluoroacetate). For the latter technique there has been a large body of research conducted to establish toxicity thresholds for different animals to 1080, including non-target species that may encounter baits incidentally during control operations (see summaries in McIlroy 1981, 1986). This large body of (mainly) laboratory-based work has proven critical in tailoring the field use of 1080 in Australia. However, much remains to be learned about factors influencing the toxicity of 1080 under field conditions (e.g. McIlroy *et al*. 1988; Saunders *et al*. 2000) and the efficacy of control operations in which the toxin is the primary tool used against wild dogs (Fleming 1996).

Recently, considerable attention has been directed to the potential non-target impact of 1080 poison baiting for wild dogs on a range of native mammal species, particularly carnivores such as the spotted-tailed quoll (*Dasyurus maculatus*). The spotted-tailed quoll is listed as a threatened species at both State and Commonwealth levels in Australia, primarily because in some areas it has undergone a decline in distribution and it is now uncommon across much of its existing range (Jones *et al*. 2003). Because of this uncommon nature, it is critical that land managers put in place measures that minimise potential risk to the species, including

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using conservative baiting techniques, wherever possible. In most States and the Australian Capital Territory this has led to the development of the 'buried-baiting' technique, in which baits dosed with 1080 are covered with soil, either within mounds of soil or sand, or buried below the surface of the ground (Glen and Dickman 2003*a*, 2003*b*). Doing this is thought to minimise the risk to spotted-tailed quolls since they are less inclined to dig for food than are introduced canids (Belcher 1998; Glen and Dickman 2003*b*).

Effective buried-baiting programs on public tenure, particularly when carried out over short periods and associated with other (adjacent) programs designed to protect domestic stock during lambing and calving, generally require access to a network of vehicle tracks for bait placement. In deeply dissected landscapes, or forested areas with no tracks and trails, it may still be necessary to undertake strategic canid control but lack of vehicular or foot access may preclude buried-baiting. In such areas baits with 1080 are typically deployed aerially, by fixed-wing aircraft or, more often, by helicopter. This method results in baits resting for differing periods on the surface of the ground. There is some evidence to suggest that this increases the potential risk of non-target species such as the spotted-tailed quoll encountering and consuming baits (Belcher 1998). Most recently, Murray and Poore (2004) unequivocally demonstrated that a large proportion of a trappable population of the species ate non-toxic baits loaded with a biomarker that were deployed aerially across a forested study site in southern New South Wales. There are also anecdotal reports that spotted-tailed quoll populations have declined in areas subject to aerial baiting (Belcher 2003), although these latter studies are speculative rather than confirmatory.

In a field situation there are potentially many factors that can influence whether or not spotted-tailed quolls locate and consume meat baits used in canid control. These factors include, but are not necessarily restricted to: (i) the number of baits deployed (intensity in time and space), (ii) the relative availability of those baits (other animal species may encounter them first), (iii) the availability of other food types (spotted-tailed quolls may prefer other food at the time), (vi) the distribution of those baits in relation to the animals, and (v) whether or not the baits are palatable to the animals (see Sinclair and Bird 1984). Each of these factors may vary from one location to another.

In this study, we further investigate the propensity of spotted-tailed quolls to encounter and consume meat baits deployed for the control of wild dogs in south-eastern mainland Australia. We were primarily interested in whether the rate at which spotted-tailed quolls ate baits varied in relation to the intensity of baiting: the null hypothesis being that the exposure rate of animals does not differ with baiting rate. To do this we subjected a known (trappable) population of animals to two different baiting trials, using non-toxic baits, and assessed the proportion of that population that encountered baits. The use of non-toxic baits instead of those dosed with 1080 was deemed appropriate, in the first instance, given the endangered status of the species. That aside, determining the proportion of spotted-tailed quolls that encounter baits under different baiting regimes is critical in understanding the potential impact of different 1080 control strategies for dogs on the species. This work extends our understanding of the issue to an environment very different from that where previous related studies have been undertaken (Murray and Poore 2004).

Materials and methods

Study area

Details of the study area have been described in a related paper by Claridge *et al*. (2004). We worked within the catchments of the Jacobs River and Ingebirah Creek, in the Byadbo Wilderness Area of Kosciuszko National Park, ~40 km south of the township of Jindabyne, southern New South Wales (Fig. 1). Within this highly dissected landscape, characterised by cliff-faces and outcrops of large granite boulders, the climate is dry, with mean annual rainfall less than 600 mm. The predominant vegetation reflects this low level of rainfall, mainly containing a white box (*Eucalyptus albens*) and white cypress pine (*Callitris glaucophylla*) community below 650 m (Pulsford 1991) with strips of ribbon gum (*E. viminalis*) in riparian areas. Above 650 m in elevation a grassy or shrubby yellow box (*E. melliodora*) woodland occurs, grading through long-leaved box (*E. nortonii*) woodland to mountain gum (*E. dalrympleana*) open forest with increasing elevation.

In late January 2003 the entire study area was burned by a severe wildfire, resulting in almost total loss of ground and shrub vegetation cover (0–2 m) and complete canopy scorch. By the time of the first baiting experiment, five months later (see below), there had been some restoration of ground and shrub cover, particularly in riparian areas. In late autumn 2004, when the second baiting experiment was undertaken, the ground cover layer was mostly restored, with canopy cover still largely absent.

First baiting experiment

The ability of spotted-tailed quolls within the study area to encounter and consume non-toxic meat baits ordinarily used in wild dog control was assessed using the biomarker Rhodamine B. There is no evidence that the addition of this biomarker to baits decreases their palatability for a range of mammals, including the target species (Fisher 1998; Murray and Poore 2004). For a full description of other properties of that biomarker refer to Fisher (1998).

In total, 60 meat baits (200–250-g pieces of beef, horse or kangaroo) were prepared for the first experiment. Initially, each bait was air-dried for at least 48 h, then injected with 50–60 mg of Rhodamine B in solution with water as per the methods described in Murray and Poore (2004). In late June 2003 these were placed on foot at fixed locations, every 250 m, along two transects crossing the study area (Fig. 1). The first transect, ~10 km in length, ran immediately adjacent to Thatchers Mountain Creek and the Jacobs River. The second transect, ~5 km in length, ran along the spur-line immediately to the east of the Barry Way, finally dropping into the drainage line of the lower section of Ingebirah Creek shortly before its confluence with the Jacobs River. Each transect was chosen to represent the major topographic features usually targeted in aerial baiting programs: drainage lines and ridges. Transect lengths were otherwise consistent with operational practice. The location of each bait was recorded using a hand-held global positioning system (Garmin GPS 12XL, Olathe, Kansas, USA) and flagged with fluorescent pink tape: this enabled return visits by foot on a weekly basis to establish whether baits had been taken by animals or not.

Post-baiting trapping

Four weeks after bait deployment, we commenced live-trapping for spotted-tailed quolls using wire mesh cat platform traps (300 × 300 × 600 mm; Mascot Wire Works, Enfield South, New South Wales, Australia) baited with fresh chicken pieces. These were set within a 20-m radius of a series of latrine sites used by the study animals, as described in Claridge *et al*. (2004). Traps were opened prior to dusk and checked within three hours after dawn each day. In instances where the same individual was caught at the same location on more than three consecutive nights in one place, traps at that location were closed. Trapping continued for 14 days, after which the number of animals in the local trappable population had reached a plateau.

Once removed from traps, captured spotted-tailed quolls were restrained and handled within a soft thick cotton bag. For the purposes of whisker sampling, each animal upon first capture was anaesthetised through intramuscular injection of Zoletil (6–8 mg kg^{-1}). Once sedated, 8–10 mystacial whiskers were plucked using tweezers, half from each side of the head. Prior to release animals were marked through implanting a passive transponder (Trovan, Microchips Australia, Keysborough, Victoria, Australia), sexed, measured and weighed.

Second baiting experiment

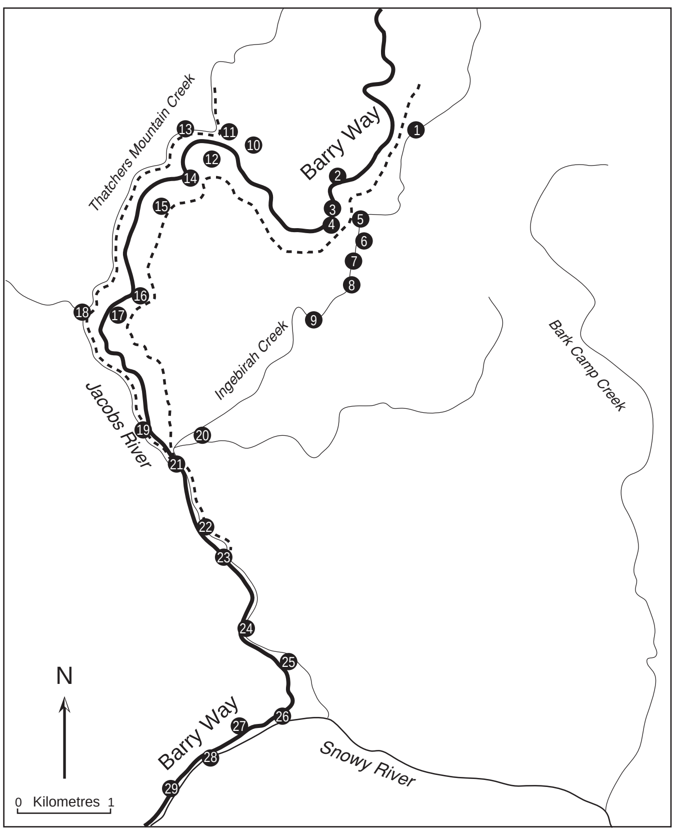
In the second experiment, meat baits were prepared in the same way as above, but instead deployed by helicopter along transects identified in Fig. 1 at a spacing of one every 100 m. This spacing is consistent with routine aerial baiting practices within conservation reserves in New South Wales. Baits were deployed in early June 2004, approximately one year after the first trial. Again, four weeks later, spotted-tailed quolls were live-captured and processed in exactly the same way as described above for the first trial.

Whisker assays

In the field, whisker samples collected from live-captured quolls were placed in appropriately labelled zip-lock plastic bags. Once in the laboratory individual whiskers from each sample were washed in 70% ethanol, to remove dirt and other debris, prior to microscopic analysis. Once cleaned and air-dried, whiskers from each sample were combined onto a glass slide, placed in mounting solution and a coverslip applied. Once the mount had dried (24 h later), samples were observed under a fluorescence microscope. Any distinctive banding of Rhodamine B observed in whisker samples (see Fisher 1998) was noted, including: (i) the position of that banding, (ii) the number of whiskers marked with Rhodamine B versus those that were unmarked, (iii) the number of individual bands per whisker, and (iv) the number of marked animals versus unmarked animals.

Results

In the first experiment, in which baits were laid on the surface of the ground at known locations, we observed that all baits were removed from these sites within one week of deployment. Since we did not place baits on a pre-prepared (sand or soil) surface, but rather tried to mimic the natural situation as closely as possible, the type of animals that removed them could not be fully determined. However, tracks recorded immediately next to bait sites included Australian ravens (*Corvus coronoides*), dogs, lyrebirds (*Menura novaehollandiae*), foxes (*Vulpes vulpes*), pied currawongs (*Strepera graculina*) and spotted-tailed quolls.



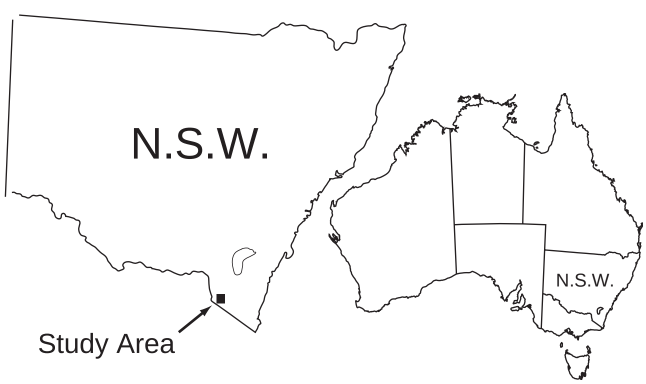


Fig. 1. Map of the study area, situated in the Byadbo Wilderness Area within Kosciuszko National Park, New South Wales, Australia. Transects where baits were deployed are shown as dashed lines. Numbered circles represent trap-site locations.

In the first experiment 10 spotted-tailed quolls were sampled (6F : 4M), with six (4F : 2M) showing positive evidence of bait consumption, as evidenced by Rhodamine B banding in whiskers (Table 1). For all 'positive' animals, there were only single Rhodamine B bands in any given whisker and not all whiskers of 'positive' animals were marked. In the second experiment, eight (4F : 4M) of 17 (7F : 10M) quolls were positive for Rhodamine B. Of the eight 'positives', four animals had more than one Rhodamine B band present in whisker samples, most likely indicating multiple bait consumption (up to five discrete bands in one individual). As in the first experiment, some whiskers from 'positive' animals did not show Rhodamine B banding (Table 1).

Seven of the 20 individuals used in the trials were common to both experiments (Table 1). Of interest, five of those seven individuals delivered a consistent result from one trial to the next. Three were found to have consumed baits in both trials (i.e. were consistently positive), two consumed baits in one trial but not the other trial and two (Animals 4 and 6) did not consume baits in either trial.

Figure 2 illustrates two whisker samples taken from an individual spotted-tailed quoll, with separate Rhodamine B bands highlighted as a bright orange halo. This indicates that the particular animal probably ate two separate baits, some time apart. There was no general pattern to the positioning of Rhodamine B in whisker samples from 'positive' animals, with the biomarker expressed in some samples close to the whisker bulb and at the distal end of the hair in others. This is not surprising since time from bait deployment to bait consumption probably differed between animals and the rate at which whiskers grow also varies (Spurr 2002).

Table 1. Rhodamine B assays of whisker samples collected from live-captured spotted-tailed quolls (*Dasyurus maculatus maculatus*) during two baiting trials conducted in the catchment of the Jacobs River, Byadbo Wilderness Area, Kosciuszko National Park, New South Wales, Australia

Each animal sampled was given a unique number, hence some individuals were common to both experiments. Trap location number corresponds to locations shown in Fig. 1. The number of whiskers marked is expressed as a fraction of the total number of whiskers assayed, with the number of discrete bands indicated in parentheses. Days after bait deployment = no. of days after deployment of bait when whiskers were sampled. Whisker samples were not taken from Animal No. 1 in 2004 trial

Animal no.	Sex	Weight (g)	Trap location	Rhodamine B	No. of whiskers marked	Days after bait deployment
2003 baiting trial (4 baits km^{-1})						
1	M	1350	22	Positive	2/9 (1)	33
2	M	1575	22	Negative	0/8	28
3	F	2050	29	Positive	2/8 (1)	40
4	M	2850	1	Negative	0/8	28
5	F	1300	16	Positive	3/10 (1)	29
6	F	1655	2	Negative	0/9	40
7	F	1325	15	Positive	8/8 (1)	33
8	M	1850	16	Positive	3/9 (1)	40
9	F	1700	21	Positive	2/8 (1)	29
10	F	1780	17	Negative	0/9	36
2004 baiting trial (10 baits km^{-1})						
1	M	2500	17	Positive	[A]	21
2	M	2500	23	Positive	2/8 (2)	22
3	F	1950	27	Negative	0/8	22
4	M	2700	2	Negative	0/8	22
5	F	1850	16	Positive	7/9 (1)	24
6	F	1800	1	Negative	0/8	24
7	F	1800	13	Positive	8/8 (5)	29
11	F	1700	2	Negative	0/9	21
12	M	3070	12	Positive	2/8 (1)	21
13	M	3800	21	Negative	0/8	21
14	F	2000	24	Positive	6/8 (1)	22
15	M	3000	15	Positive	5/9 (2)[A]	22
16	M	1700	11	Negative	0/8	22
17	F	1450	20	Positive	7/7 (3)	24
18	M	3450	2	Negative	0/8	24
19	M	2075	16	Negative	0/8	28
20	M	3000	22	Negative	0/8	28

[A]Individual egested faeces with Rhodamine B biomarker present.

Discussion

Encounter rates

Our results reaffirm the earlier work of Murray and Poore (2004) that clearly identified the ability of spotted-tailed quolls to encounter and consume non-toxic meat baits deployed for control of wild dogs in south-eastern Australia. In this respect the foraging behaviour of the species for that food item seems to be common to at least two widely different habitat types: wet sclerophyll forest in the former study and rainshadow woodland in this study. Intriguingly, the encounter rate, or proportion of trappable animals that ate baits compared to those that did not, was not very much different between studies, despite markedly different baiting rates. In the work of Murray and Poore (2004), baits were deployed at a rate of one bait every 25 m, or ~40 baits km^{-1}. This resulted in 63% of animals encountering baits. In our studies, where baits were first deployed every 250 m (4 baits km^{-1}), then every 100 m (10 baits km^{-1}), the encounter rates were 60% and 47%, respectively.

Intuitively, there are good reasons why there should be no direct or linear relationship between number of baits deployed and encounter rates by the study animals. First, an individual quoll ultimately occupies only a certain area, and there is at least some form of spatial segregation of animals (Claridge *et al*. 2005), resulting in differing densities of animals at any one point in time and space. This means that not all animals within a population will have ranges that overlap with where baits occur. Second, at any given time spotted-tailed quolls may be consuming a variety of prey, including carrion, and the availability of those items will vary in space and time. Thus, in one area there may be few baits but high availability of other prey items, and *vice versa*. Third, not all animals will necessarily be (behaviourally) inclined to eat carrion, even if available. Fourth, spotted-tailed quolls are not the only animals that encounter and consume baits. Other species that may be particularly likely to encounter and consume baits include wild dogs, foxes, feral cats (*Felis catus*) (McIlroy *et al*. 1986; Fleming 1996) and various forest-dwelling birds (Allen *et al*. 1989). The rate at which these other animals encounter and consume baits will vary and impact to varying degrees upon the availability of baits for quolls to encounter and consume.

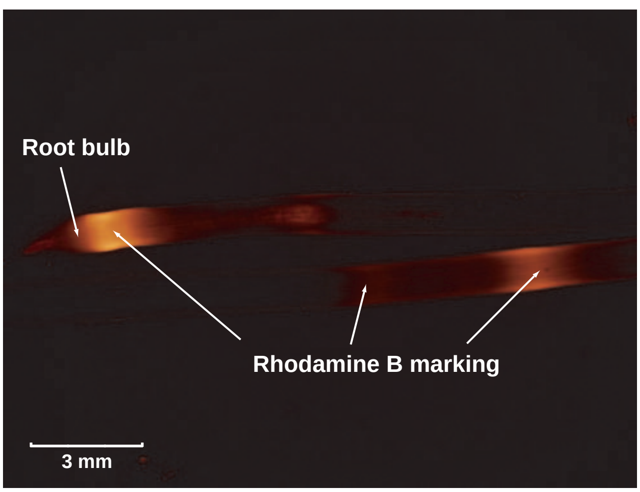


Fig. 2. Rhodamine B banding in whisker samples from a spotted-tailed quoll (*Dasyurus maculatus maculatus*). The biomarker shows as a bright orange halo in discrete bands.

One common-sense matter is clear from the three sets of non-toxic trials so far conducted: when baiting rate increases there may potentially be more opportunities for individual animals to encounter baits, resulting in more baits being eaten by that individual. When baiting rate was increased in our study we encountered animals that had consumed more than a single bait, a phenomenon not seen when baits were widely spaced. Murray and Poore (2004) also observed a similar pattern, in that a very high baiting rate resulted in some animals eating multiple baits. How these results would apply in a situation where toxic baits were used is unclear, since previous research has indicated that an animal may reduce bait consumption after initial exposure to 1080 (Sinclair and Bird 1984).

Risk versus mortality

Although our study and that of Murray and Poore (2004) are instructive in reaffirming the ability of spotted-tailed quolls to encounter and consume (unpoisoned) meat baits used in wild dog control, they do not provide much guidance in relation to impact of 1080 on the species. In brief, we have only assessed extreme risk, not actual mortality, of animals. In the first instance our conservative approach in not undertaking this trial with poisoned baits is prudent given the endangered conservation status of the species. However, the results of a simulation using non-toxic baits may not accurately reflect the impacts of real canid-control programs, in which baits containing 1080 are deployed. So far, the impact of aerial baiting on spotted-tailed quolls has only been inferred from population studies where local declines have been observed in the presence of a baiting activity (Belcher 2003). The overwhelming limitation of such studies is that causation has not been demonstrated, but alluded to.

In the work of Belcher (2003), the fate of all but one animal in the study populations was not determined – they merely could not be accounted for. There are several plausible reasons why this may have been the case, including: (i) there were no nil-treatment sites in Belcher's (2003) study so it is impossible to assess changes in quoll abundance as a result of baiting, (ii) capture efforts before and after baiting events may have been unequal (these were not reported, thereby preventing analysis); (iii) animals simply were alive but not trapped subsequent to the baiting events; (iv) the animals died through natural causes (e.g. Körtner *et al*. 2003); (v) there were seasonal changes in home-range size or use; and (vi) other factors reduced habitat quality and animals moved outside of the trapped area. Either way, our view is that the impact of 1080 baiting on the species may have been overemphasised. The only way to know is through objective study, either through further trials (see below) or by closely monitoring the ongoing fate of spotted-tailed quoll populations under different canid-management regimes. None of these studies will be easy to conduct; nevertheless, they are critically important.

Although laboratory-based studies have suggested that spotted-tailed quolls may be sensitive to 1080 poisoning (McIlroy 1981, 1986), the response to the toxin in the field may be quite different. Compound 1080 is not a stable chemical, inasmuch as it does degrade when deployed in the environment. For example, McIlroy *et al*. (1988) investigated the effect of rainfall and blowfly larvae on the toxicity of 1080 meat baits. They determined that baits deployed in winter would still retain an LD_{50} for spotted-tailed quolls with a mean weight of ~2.8 kg for 4–15 days. In another study, Fleming and Parker (1991) found that fresh meat baits injected with 5.3 mg of 1080 and placed in the field for 20 days still retained a mean amount of 1080 of 3.4 mg. On the basis of the earlier work of McIlroy (1981, 1986), this amount would be enough theoretically to kill 50% of spotted-tailed quolls weighing up to 1.84 kg. These studies indicate that although a meat bait may theoretically contain a lethal dose of 1080 for a spotted-tailed quoll upon preparation, it may not by the time that bait is encountered in a field situation. Many other factors may also influence whether or not that bait is actually lethal for the animal consuming it: (i) the animal's body weight and health status, (ii) how much of the bait is consumed, (iii) how much 1080 is contained in that proportion of the bait it consumes, and (iv) how much 1080 is assimilated upon ingestion. Finally, there is some evidence to suggest that animals regularly exposed to 1080 in a field situation may either have an innate and/or learned aversion to consuming baits (Morgan 2004). All of this raises more questions than answers about the impacts of 1080 on the species.

Future research

Ultimately, from a management perspective, it is the net impact of canid-control operations on any given population of spotted-tailed quolls that is the critical issue. In at least some circumstances, baiting for canids, particularly foxes but perhaps also wild dogs, may benefit spotted-tailed quolls through numerical reduction of potential competitors for food (see diet study of species by Belcher 1995). Apart from direct or exploitation competition, spotted-tailed quolls may also suffer through interference competition from foxes by being excluded from certain areas of habitat, and may even be directly killed by them (Körtner *et al*. 2004; Glen and Dickman 2005). Thus, while there may be some mortality of spotted-tailed quolls during control operations, that loss incurred may, in fact, be less than if no control were undertaken at all. Provided the local population has the reproductive potential to recover from any numeric loss caused by the baiting, then the net impact of that event may be positive. For this reason alone we see it as critical to further examine the issue of 1080 impacts on spotted-tailed quolls by addressing the vital subject matter of risk versus actual mortality of animals during aerial baiting in the field.

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